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目　　次

操舵手により操舵中の船舶のヨーイングについて—I …… 高 島 末 夫 …… 1

二艘曳機船底曳網の模型実験—II
S—I 型網の模型実験ならびにその漁獲効果について …… 谷 口 武 夫 …… 9

油なめし法の検討 その六 …… 松沢定五郎 …… 37

油なめし法の検討 その七 …… 松沢定五郎 …… 43

Food-relations among the Fish Caught by the Set-nets along the Arikawa Bay (at the Middle of the Goto Islands) during the Period from Late Autumn to Early Winter …… Hiroshi MAÉDA, Hirotaka MATSUOKA and Isao MATSUI …… 53

Morphometric Characters of Yellowfin Tuna, *Neothunnus albacora* (LOWE), in the Southwestern Waters of the Indian Ocean (off the Southwest of the Madagascar Island) …… Saburo TSURUTA …… 75

Contents

Yawing of Ships on the Steering by Quartermaster— I ..... Sueo TAKASHIMA 1

Model Experiment on the Japanese Two-Boat-Type Trawl Net— II
Model Experiment on *S—I* Type Net devised newly, and Consideration upon the Efficiency of the New Devices connecting with the Behaviour of the Object Fishes ..... Takeo TANIGUCHI 9

Considerations on Oil Tanning (6th) ..... Jōgorō MATSUZAWA 37

Considerations on Oil Tanning (7th) ..... Jōgorō MATSUZAWA 43

Food-relations among the Fish Caught by the Set-nets along the Arikawa Bay (at the Middle of the Goto Islands) during the Period from Late Autumn to Early Winter ..... Hiroshi MAÉDA, Hirotaka MATSUOKA and Isao MATSUI 53

Morphometric Characters of Yellowfin Tuna, *Neothunnus albacora* (LOWE), in the Southwestern Waters of the Indian Ocean (off the Southwest of the Madagascar Island) ..... Saburo TSURUTA 75

操舵手により操舵中の船舶のヨーイングについて—I.※

高　島　末　夫

Yawing of Ships on the Steering by Quartermaster—I.

By

Sueo TAKASHIMA

In general, when a ship is going along a straight course it has scarcely any possibility of keeping her appointed course without steering. The ship is always inclined to yaw due to the external disturbances from such factors as wind, sea wave, *etc.* and the subsequent steering to it sometimes contributes also to her greater yawing, and so it is impossible to prevent her from yawing perfectly. Actualy, in order to put her in course, the helmsman is obliged to regulate her course unintermittently.

Sometimes, the steering may cause a yawing of large magnitude such as those beyond the natural one by waves. This brings her to meandering movement; therefore, its effect on the propulsion can not be overlooked.

The author investigates in this paper into the yawing, employing the records of an actual ship steered by some quartermasters, from navigators' point of view, especially about the magnitude of amplitude and its variance, and appendantly, the periodicity of magnitude of amplitude. And the following results are obtained:

1) The yaw-angle during the navigation varied complicatedly. But the author can find out any significant difference neither in the average nor the deviation of the magnitude of yaw-angle between both sides and among the quartermasters.

2) The periodicity in the magnitude of the yaw-angle is neither in common with the sides and the quartermasters nor its magnitude fell into simple decaying.

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緒　　言

航行中の船舶は与えられた針路を航行するためにほとんどたえまなく操舵が行なわれ，保針のための舵角の大きさの変化は気象海象等の外的因子，船舶の保針性，舵角に対する追従性或るいは操舵手の技能等の内的因子により予想より遙かに複雑な様相を示しており，その結果としてヨーイングの形態もかなり複雑なものと考えられるので，小数例をもってその全貌を完全に明らかにすることはできないが，一応代表的と思われるものについて解析した。

航行中の船舶のヨーイングは波圧によって生じるヨーイングと長周期（約70～200秒）で大角度のヨーイングが重なったものがみられる。元良（1954）[1] によれば，前者はその振幅が大体理論的に予想される量と一致しており，周期も波の出合周期と一致しているのが認められ，このために著じるしく推進性能が害されることはない。しかし後者の場合即ち，操舵によるものと思われる大角度のヨーイングについては，ほぼこれと同じ周期で大角度の操舵が行なわれているものと考えられ，操舵手による操舵では不必要な蛇航を生じさせているものと思われる。

波圧により生じたヨーイングが当然記録されるはずであるが，資料を採用した耕洋丸に使用しているコースレコーダーは，機構上感度が不十分で記録紙の中で大角度のヨーイングと識別できなかった。そこでこの報告では，大角度のヨーイングが主として操舵手の操舵により誘発されたものとして若干の考察を行なった結果についてのべる。

資料および方法

資料は耕洋丸が操舵手により保針航行中コースレコーダーが記録したうちから，8時間連続したものを採用し，その間の気象海象の状況および船の状況は下記のとおりで，全期間を通じて大体変化がなかった。

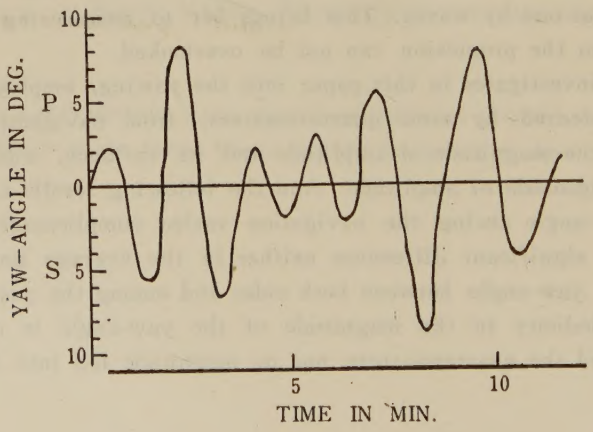

Fig. 1. An example of the actual yawing traced by course-recorder.

Abbreviations, S : Starbord　　P : Port

排水量　1,800 トン
トリム　2.0 m 艉え

舵面積比	$\frac{1}{39.8}$		
真針路	N30°E	速　力	13.0ノット
真風向	SE	風　力	5（ビューフォート階級）
海　況	4		

コースレコーダーの記録紙の模写を第1図に示す。大角度のヨーイングが針路からのズレという悪影響を起こすことを考えると，ヨーイングの大きさは片舷の偏角の大きさ即ち，第1図に示すように全振幅の½の値をとって考えるのが都合が良く，この報告では，偏角の大きさは片舷の偏角の大きさを示すものとする。

また一般に航行中の操舵当直は，1時間毎に操舵手が交代するから資料を8個の層A，B，C，……Hに区分し，各層は同一の操舵手が連続して操舵したものとみなした。

考　　察

1. 振巾の大きさと分散

船舶が航行中大角度のヨーイングが連続すれば当然回頭遠心力の分力，舵の抵抗，斜航のための抵抗，走航距離の延長，操舵機の馬力損失等綜合的に船舶の馬力損失となり，運航上極めて悪い結果をもたらすが，

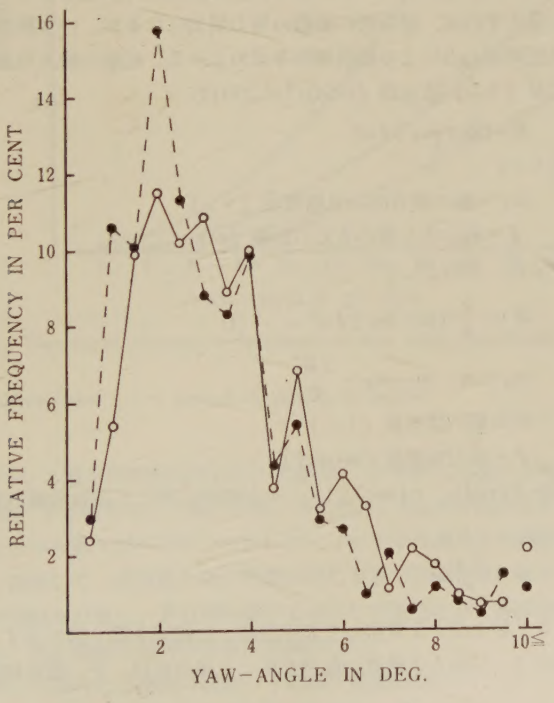

Fig. 2. Relative frequency in relation to yaw-angle.
Note. Filled circle indicates the relative frequency of starboard side, but open one does that of port side.

現実の問題として操舵手により保針航行中には或る程度のヨーイングは避けられない。その結果上記の馬力損失も或るいは不規則なヨーイングにより推定位置に誤差を誘発させるのも，その影響の程度に差異あるが防止することはできない。

この意味において操舵によるヨーイングは，その因果たる舵角および偏角ともに努めて小角度に押さえるべきであるが，航行中外力や操舵により発生しているヨーイングの大きさおよび分散の状況，或るいは発生したヨーイングの頻度を知り，それらが気象海象，時刻的或るいは操舵手相互の間でどのような相関があるかを知るのも，船舶運航者の立場から必要であると考え資料を分析した。

全資料のヨーイングについて偏角の大きさと，発生した相対頻度の関係を第２図に示す。偏角の大きさを前述の定義に従ったため相対頻度分布曲線のモードは小角度になり，両舷ともに指数型に近い型をなすものと考えられる。両舷ともに偏角２度の頻度が最大となり，当時の気象海象のもとではこの程度のヨーイングは避けられない。またこれらのヨーイングの中には波圧によって生じたものも含まれていると思われるが，この範囲のヨーイングは推進性能に大きい悪影響を与えない。

７度～９度の偏角を生じた頻度が両舷平均約1.5％みられ，発生頻度の点では問題とするほどではない。しかし，この相対頻度分布曲線に示されている10度以上のなかに偏角の大きさが15～16度から20度以上にいたるものが含まれていることは注意しなければならない。このような大きい偏角を生じた原因は複雑であるが，通常考えられる主な原因は，操舵手の過当操舵によると思われる。またこれらの大きい偏角を生じた場合には，当然原針路に復帰させるため相当大きい舵角が取られたことが予想され，結果的に船体運動は回頭角速度の大きい蛇航を誘発し，次に述べるように推進性能に極めて悪い影響を与える。従って発生頻度は少ないが，運航上の損失は大きく，努めてこれらの発生を防止させなくてはならない。

大角度のヨーイングが発生すれば，綜合的に船舶の馬力損失になるが，いま耕洋丸について偏角の大きさと，それにより発生する蛇航遠心力による抵抗増加を求めてみる。蛇航の最大角速度を ω とすれば，遠心力の船体中心線方向の分力 R（トン）は元良（1954）[1]によれば，

$$R=(m+m_y)\ell\omega^2$$

但し　m＝船の質量（トン）

m_y＝船の横方向の見掛質量（トン）

ℓ＝転心より重心までの距離（m）

これが周期的に作用するから，平均として

$$\overline{R}=\frac{2}{\pi}(m+m_y)\ell\omega^2 \cdots\cdots\cdots(1)$$

$$m_y \fallingdotseq m \quad m+m_y=\frac{2W}{g}$$

W＝船の排水量（トン）

g＝重力加速度（m/sec^2）

偏角の大きさおよび周期を θ(rad)，τ(sec)とし，θ が時刻に対して正弦曲線の変化をするものと仮定すれば，

$$\omega=\frac{2\pi}{\tau}\theta$$

にて示される。(1)式により τ および θ を変化して $\overline{R}$ を計算した結果を第３図に示す。この図に示されるようにヨーイングの周期が短かく，しかも大角度の偏角を生じた場合には，その抵抗増加量も無視できないものである。

７度以上の大きい偏角がほぼ両舷等しい頻度で発生しているが，資料を得た当時の気象海象等の外的因子にはこのようなヨーイングを発生させる強制外力は考えられない。この大きい偏角を生じた原因は，操舵手が船の予定針路からの偏角とその回頭角速度に比例した舵角を適切に与えていれば，偏角は少なくとも２度

前後に押さえることができるが，操舵手の人為的な何等かの原因で偏角に対して適切な舵角が与えられなかったためと考えられる。従って操舵手により保針航行中に現われる船舶のヨーイングは，操舵手の複雑な人為的因子の影響を受けて変化しているものとみられる。

この点から操舵手相互間および同一操舵手において，両舷の偏角の大きさおよび分散の状況を調べた。この種の調査では第2図の分布曲線を正規型に近づける必要がある[2]。そこで，この資料の偏角の大きさ θ に

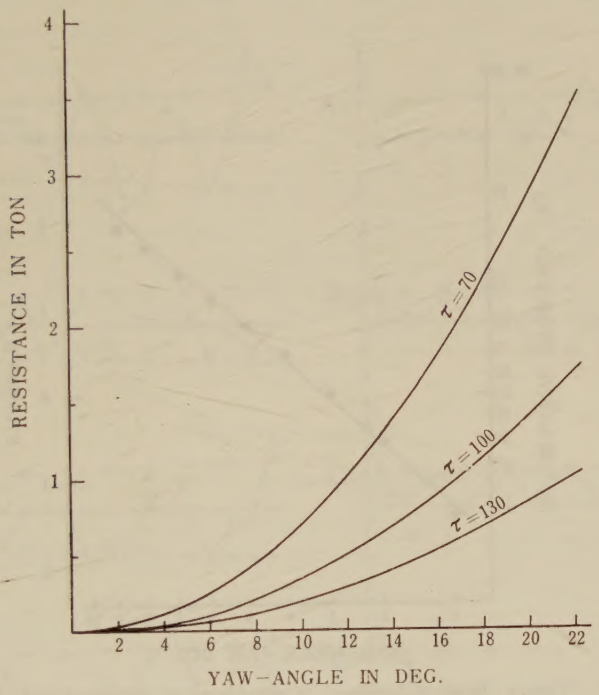

Fig. 3. Theoretical increase in resistance of ship with centrifugal force.

Abbreviation　τ = period of yawing in second

ついて $\sqrt{\theta}$ および $\log\theta$ の2種の変数変換を行なった結果，いずれも完全に正規型化されず，STUDENT の "t" とこれらの関係は $\sqrt{\theta}$ の場合はごく微小だが，下に凹み，$\log\theta$ の場合はその反対となった。その1例として $\sqrt{\theta}$ に変換したものを第4図に示す。しかしヨーイングでは通常 θ の範囲が狭いので，$\sqrt{\theta}$ 変換で大体直線になったものと仮定して，妥当性を欠く現象が生じるまで正規化されたものとして考察をつづける。

各層の偏角の分散，平均値を計算し，F分布に従うものとして検定し次の結果を得た。

(1)　操舵手8名のうち7名が両舷の偏角の分散に差異がない。

(2)　同一操舵手が操舵した場合には両舷の偏角の平均値に差異がない。

(3)　操舵手相互間の偏角の分散の差異は7組中全組が認められない。

(4)　操舵手相互間（7組）には偏角の平均値の差異は認められない。

以上(1)～(4)がいずれも5％の危険率で有意である。

この結果から操舵手により保針航行中に現われる船舶のヨーイングは，発生するヨーイングの個々につい

ては操舵手の個人差（例えば舵角の大きさ，舵角角速度およびそれに対するヨーイングの周期，角速度）が現われてくるが，或る期間に発生したヨーイングを統計的にみれば，そこには個人差が比較的現われていないといえる。また両舷に現われたヨーイングの分散，平均値に差異が認められないのは，船首方位は予定針路をほぼ中心として航行しているが，船位は必ずしも予定針路を航行しているとは限らず注意しなければならない。なお操舵手8名のうち1名だけが両舷の偏角の分散に差異が認められたが，当時の人為的状況が不詳のためその原因は明らかでない。

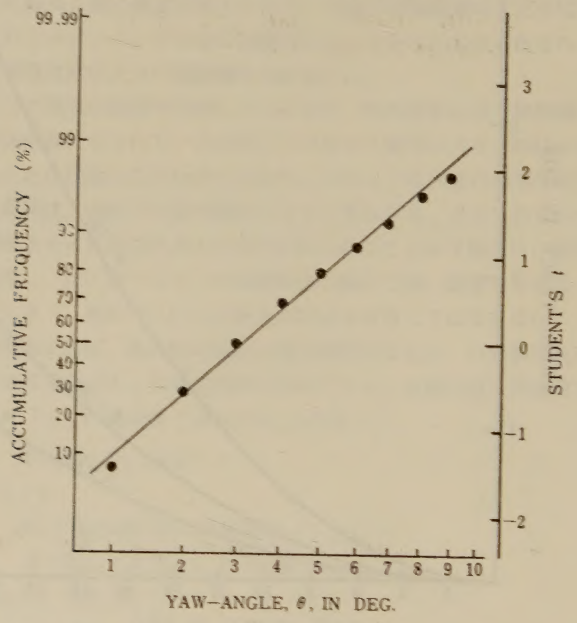

Fig. 4. Relative frequency in relation to θ in square root scale, with reference to "STUDENT'S t"

2. ヨーイングの周期性

船舶に作用する強制外力の不規則性は船の運動に種々の影響をもたらすが，一般的にみて規則的な外力が船におよぼす影響よりも或る程度減少するものと考えられている。従って船のヨーイングの如く個有周期をもたないものに対しては周期の不規則性は大して影響しないが，外力の大きさの不規則性が問題になる。一方大洋における波浪には4～6回目毎の周期で波高の特別大きい波浪がくる場合がある外，風力もその大きさにより10～20分の周期をもち一時的に強まる場合がある[3]。

ヨーイングに影響をおよぼすと考えられる強制外力に以上のような周期性があることを考え，しかもこれらの外力が船に作用したとき，偶然に偏角を助長する方向に他の回頭モーメントが作用していれば，偏角は一時的に相当大きくなるものと考えられる。また操舵手により保針されているときは大きい偏角を生じたのちしばらくは操舵に注意するが，時間を経て再び大きい偏角を発生するという過程を繰り返しているものと思われる。

いまコースレコーダーにより得られたヨーイングの連続記録（第1図参照）をみると，これは時間とともに

に変動する定常時系列をなし，また偏角の大きさがヨーイングの発生順位とともに変動する定常時系列をなしているものと考えられる．ここでは後者の考えに従って時系列解析を行ない，各層毎に母集団としての確率過程を求め，これによってヨーイングの周期性を考察してみる[4]。

各層毎に片舷ずつの連続記録から操舵系列の相関係数即ち，ヨーイングの発生順位毎に記録したN個の偏角 θ_1, θ_2, ……θ_nの相関係数r_kは次式で求められる。

$$r_k = \frac{1}{N-k}\sum_{i=1}^{N-k}(\theta_i-\bar{\theta}_1)(\theta_{i+k}-\bar{\theta}_2) / S_1 S_2 = \left(\frac{1}{N-k}\sum_{i=1}^{N-k}\theta_i\theta_{i+k}-\bar{\theta}_1\bar{\theta}_2\right) / S_1 S_2 \cdots\cdots(3)$$

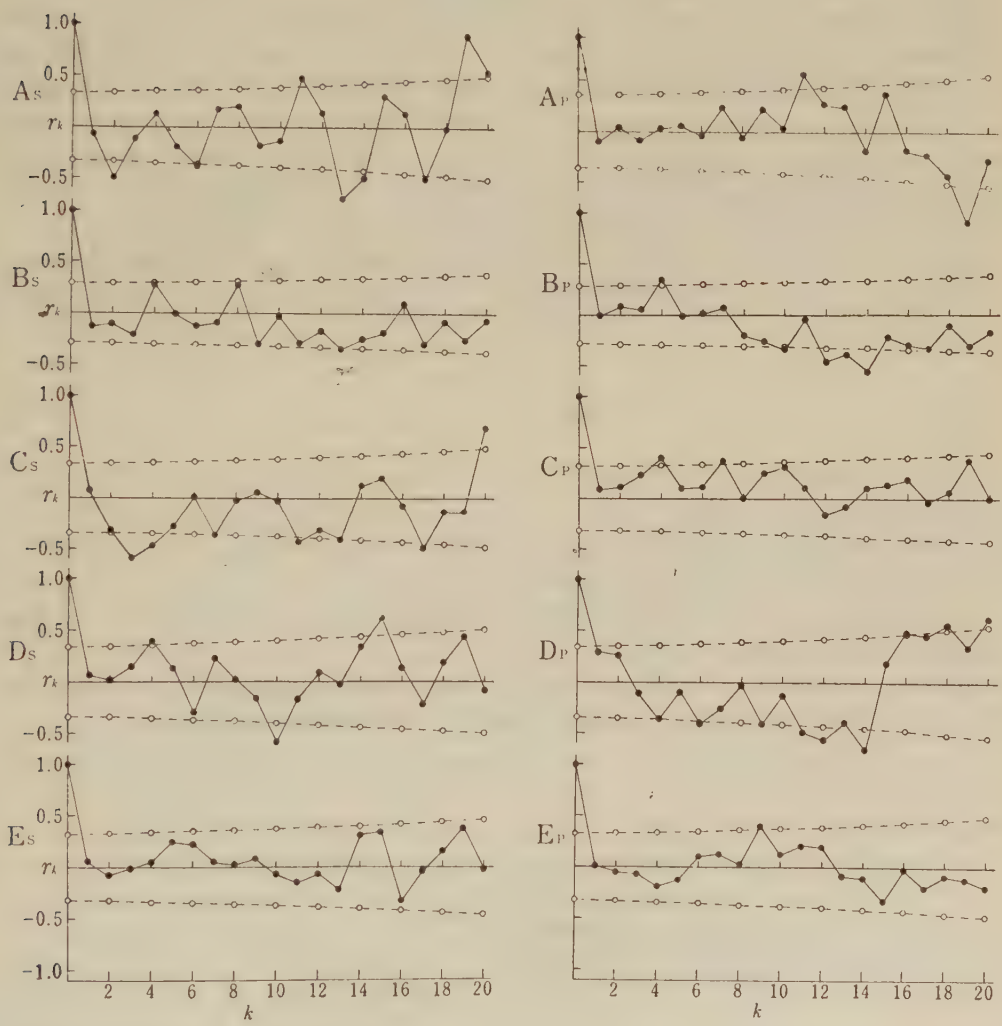

Fig. 5. Correlograms of yaw-angle.

Notes k : Counted in the occurrence order in yaw-angle

A～E : Symbols of quartermaster

Suffix S and P : starboard and port, respectively

Filled circle indicates the computed value from the observed series of yaw-angles, and open one does the lowest limit of r_k, the value higher than which can be regarded as significant at 0.05 level.

但し　$\bar{\theta}_1 = \sum_{i=1}^{N-k} \theta_i/(N-k)$　　$\bar{\theta}_2 = \sum_{i=k+1}^{N} \theta_i/(N-k)$

$S_1^2 = \sum_{i=1}^{N-k} (\theta_i - \bar{\theta}_1)^2/(N-k)$　　$S_2^2 = \sum_{i=k+1}^{N} (\theta_i - \bar{\theta}_2)^2/(N-k)$

A，B，C，D，Eの各層両舷について(3)式によりr_kを計算して得たコレログラムを第5図に示す。この図の横軸は連続した偏角の第1番目（k＝1）～第20番目（k＝20）を意味し，曲線は自己相関係数の有意水準5％のものをとって示してある。

第5図から直観的にわかるのは船のヨーイングが決して単純な自己回帰過程をとるものでなく，また簡単な減衰過程をもつものでもないということである。これは船のヨーイングが横揺れ等の如く個有周期をもたず，しかも操舵手の操舵過程が極めて複雑なものであるためと考えられる。しかし各層の右舷或るいは左舷についてコレログラムを各個について考察すれば，その間に発生したヨーイングについて大体の様子が推定できる。例えば第5図 As では連続的に発生しているヨーイングのうち第11回目毎および，第19回目毎に現われる偏角は相当大きい有意な周期が認められる。また同図 Ap では As と同様に，第11回目毎に大きい偏角を生じる有意な周期があるが，第19回目毎には大きい偏角を生じないことが予想される。As，Ap ともに上記の周期以外は有意なものが認められないが，大体4回目を基底として4の整数倍の回数目毎にかなり大きい偏角を生じる性質がみられる。この原因はコレログラムの偶然性の外種々あるが，この資料だけでは明らかでない。

結　　論

操舵手により操舵保針されている実船に現われたヨーイングについて，若干の仮定のもとに解析したところを総括すると次のようである。

（1）航行中偏角は極めて複雑な変化をしているが，その大きさについて分析してみると，各舷並びに操舵手相互間に平均値，分散の差異はほとんど認められない。

（2）偏角の大きさについての周期性は，各舷ならびに各操舵手間に共通した周期性はなく，また単純な減衰過程をとるものでもない。

終りに臨み，この研究に対して終始ご指導を賜わった本所杉原喜義教授，同前田弘博士の両氏に厚く御礼申し上げるとともに，資料を提供された元耕洋丸一等航海士隅川芳雄氏に感謝の意を表する。

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4）山内保文，1956：船の動揺の時系列論的解析について．造船協会会報，**99**．

二艘曳機船底曳網の模型実験 Ⅱ.

S—I 型網の模型実験ならびに その漁獲効果について※

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Model Experiment on the Japanese Two-Boat-Type Trawl Net—Ⅱ. Model Experiment on *S—I* Type Net devised newly, and Consideration upon the Efficiency of the New Devices connecting with the Behaviour of the Object Fishes※

By

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It is very natural that, when we wish to catch effectively some of demersal fishes, such as yellow croaker, Yellow Sea prawn, hairtail and so forth, which frequently come up to a little shallower layer than the bottom, the level of the net head should be heightened into the layer shallower than their swimming depths.

New devices are made to attain the above-mentioned point by improving the gears conventionally employed in the commercial fishery.

Their theoretical approach and its expansion are schematically represented in Figs. 1 and 2. Plans of the gear constructions used in the field experiment based on the above-mentioned theories are illustrated in Figs. 3 and 4 (*S-I* type net).

The working behaviours of this new type net were discussed adopting TAUTI'S law of comparison of fishing net, refering to those of the ordinary type net which were already reported in the first report of this series.

Incidentally, the practical fishing-effect of this new type net for several bottom fishes of importance such as the above was discussed, on fishermen's suggestion and behaviours of these fishes through the fishing echo finder, refering to that of the ordinary one.

And following results are obtained:-

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1) When the distance between two spreaders attaching to each frontal end of the wings is narrower about 30 m, the horizontal opening at the net-mouth increases considerably with the distance, but when the distance becomes wider than 30 m, it is almost invariable, regardless of the distance. While, except for when the distance between two spreaders is extremely narrow, the vertical opening at the mouth is always constant, too.

The rates of increase in the horizontal opening or of the decrease in the vertical one of this new type net, are not so marked as that of the ordinary type one. And the absolute value of the horizontal opening at the net-mouth on this new type net is always smaller than that of the ordinary one, but its vertical opening is contrary (Plate 1, Figs. 5 and 6).

The towing resistance increases markedly with the distance between two spreaders, and the rate of increase in the resistance of the net is, when the distance between two spreaders is wider than about 30 m, greater than when it is narrower than it. And the absolute value as well as the general rate of increase in the resistance is, on this new type net, markedly greater than those of the ordinary one (Fig. 7).

2) When the towing speed is lower than about 1 mile/hour, the horizontal opening at the net-mouth increases just a little with the increase in the towing speed, while vertical one decreases equally with it. But when the speed becomes higher, the horizontal opening as well as the vertical one is almost constant, regardless of the speed.

The rate of increase of the horizontal opening on this new type net is similar to that of the ordinary one, but its absolute value is always smaller than that (*i.e.*, the former is measured about 1.6 % as smaller as the latter at 2.5 miles/hour towing speed). On the contrary, the rate of decrease of the vertical opening on this new type net is insignificant in comparison with that of the ordinary one, but its absolute value is always larger than that (*i.e.*, the former is measured about 2 times as large as the latter at 2.5 miles/hour towing speed) (Plate 2, Figs. 8, 9 and 11).

The towing resistance increases nearly in proportion to the square of the speed. This fact is just the same on both this new type and the ordinary type net but the former is, always, about 1.4 times as large as the latter at the absolute value (Fig. 10).

3) When the towing speed is very slow, the float attached on the net is effectually to keep the net-mouth on high. But when the towing speed becomes higher than 2~3 miles/hour, it is not so effectual, but a limit of its effect is better than the result of the ordinary type one. Namely, the variation of the buoyancy, within a certain limit, of the float attaching to the net-mouth and its neighbourhood makes little change in the vertical opening of the mouth, so for as the towing speed is not lower than 2~3 miles/hour. But however much the buoyancy may increase by some measure, it brings about the floating up of the net without increasing the vertical opening at the net-mouth.

When the towing speed is not lower than 2~3 miles/hour, the net-mouth is kept in some height by the action of lifting force working on upper net such as the square

and upper wing net and *etc.*, even the strip style net without float, but the ordinary type net never does so (*i.e.*, it is measured about 2.5 m in height, on this new type net, under 2.5 miles/hour towing speed and 33.2 m in the distance between two spreaders, while it is measured 0 m in height on the ordinary one, too.).

Lifting force on upper net is, thus, very large. This comes to floating up the ground rope near the net-mouth in normal state net with float. It is, therefore, impossible to keep the ground rope on the bottom except attaching the chain at least twice as heavy as the ordinary one (Figs. 12, 13, 14, 15 and 16).

4) The merits and demerits of commercial fishing-effect of this new type net, for the important bottom fishes caught in the East China and Yellow Sea, against the ordinary one, are difficult to make a sweeping statement, because their behaviours differ with primary factors such as species, fishing season, fishing ground, day or night, ebb or flow, and *etc.*

But generally speaking,

a) For spring-and summer-yellow croaker (*Pseudosciaena manchurica*) caught from the latter part of March to the middle of April and from July to August, the fishing by new type net surpasses it by the ordinary one in fishing-effect, but for autumn-yellow croaker caught from September to November, it surpasses rather the latter than the former (Figs. 17 and 18).

b) For Yellow Sea prawn (*Penaeus orientalis*) caught in the fishing ground south of 45°—30′ N lat. from the beginning or the middle of January to the beginning of March, the fishing is made possible by this new type one alone, while for they caught in the fishing ground of north of 45°—30′ N lat. from the beginning of December to the latter part of it or the beginning of January and from the latter part of March to the beginning of April, the fishing effect surpasses rather the ordinary one than this new type one (Figs. 19 and 20).

c) On the other fishes, for hairtail (*Trichiurus lepturus*) and sharp toothed eel (*Muraenesox cinereus*), the fishing by this new type net surpasses it by the ordinary one in fishing-effect, while for white croaker (*Argyrosomus argentatus*), red sea bream (*Chrysophrys major*), yellow sea bream (*Taius tumifrons*) and flat fishes, it surpasses rather the latter than the former.

緒　　言

前報5)では，在来の網具をいかに改良すれば，より効果的に網口を高めることができ，更に上層水域の魚群をも併せ漁獲することができるかを推知する予備試験として，網口の高さに関係すると考えられる各種要因について実験し，その結果を検討した。それによると両手木間隔（両船間隔），曳網速度ならびに浮子類の配置，或るいは浮揚力の増減等，網具の操作ならびに調整上の要因は，網口を高めるという観点からは大した意義は認められず，主に網具自体の構成法いかんにかかり，これを工夫改良することで，或る程度の目的を達することができるということを述べた。

引き続き本報では，それらの諸結果をもとに在来の網具に種々工夫を重ね，その初段階としてまず網口の高さを2倍程度高くなるよう改良を加えた$S-I$型網の模型網を作製した。

これが在来の網具と較べて力学的にどれほどの差異があるものか，前報と同様各種条件下における網成りならびに抵抗変化を，水槽実験により観測し，それらの結果を比較検討した。

更に，これが実際操業上，対生物的にもどれほどの効果があるものか，以西漁場における２，３の重要魚種を対象にして，最近の魚探の記録や現場当事者等の体験報告等にもとづいて，両網具の漁獲性能の比較結果をも検討し，附記することにする。

網口の高さと本改良型網の基礎的考察

一般に底曳網の網口の高さは，第１図に示したように網口部に作用する外力，特に上向きに働く浮子類による浮揚力Fとその反対方向に働くヘッドロープ，マンロープ等にかかる張力Tの相対的な力の大きさによって左右される。A図は網口部を前面，B図は側面からみた場合の外力の作用する状況を表わした模式図で，

〔A〕　　〔B〕

Fig. 1. Schematic representations of relation between height of net-mouth and external forces working on it.
Note ; 〔A〕 and 〔B〕 show the front- and the side-view of the net-mouth and its neighbourhood, and point X and Y show the middle and both sides of frontal edges of the square part, respectively. Moreover, F, T and φ express the force working on float attaching to the net-mouth, the tension working on head rope attaching to one and the oblique angle of the face YXY to the current, respectively.

図中の点Xは天井網前端中央，点Yは同前縁両脇端が袖網部と接合される個所を示す。即ち，網口を高めるためには基本的に$F\cos\theta$を増大させるか又は，各部の$T\sin\alpha$等を極力小さくするよう工夫し，網口の主要拠点X，Y等を低下させないようにすることである。また二義的ではあるが，天井網を流れに対して適当に傾斜させ，これに揚力が生じるような方法を講ずることも更にその効果を上げるのに必要なことである。

しかしながら，在来の網具では前報[5]の結果からもわかるように，曳網速度が相当大きくなると普通の球浮子による浮揚力はその部のロープにかかる張力の大きさに比し極めて小さく，ほとんど問題にならない。また手木の長さ，網地にかかる抵抗の減少等のことがらも，それぞれ各種の制約を受けてほとんど期待できない。また天井網部も曳網中には各部が予想外に大きく低下し，流れに対し水平もしくは曲折，波状現象を呈し，一般にはこれに揚力が生じるとは考えられない。従って問題はいかにして網口附近のロープにかかる張力を減少させるかにあるが，その方法として網口附近の特定個所に特殊補助力網を取り付け，これに張力の大部分を移行させることで，既存の網口部のロープにかかる張力を減少させ，網口各部を低下させないようにすることを試みた。

第２図は網口附近のヘッドロープの長さを様々に変え，また特定各個所に補助力網を取り付けた場合の，静止時〔A〕ならびに曳行時〔B〕の網成りをそれぞれ推定し，模式的に比較したものである。図中Ⅰは在来の網具，ⅡおよびⅢはそれぞれ天井網前縁の長さをⅠより短かく或るいは長めた場合のそれであり，Ⅳは

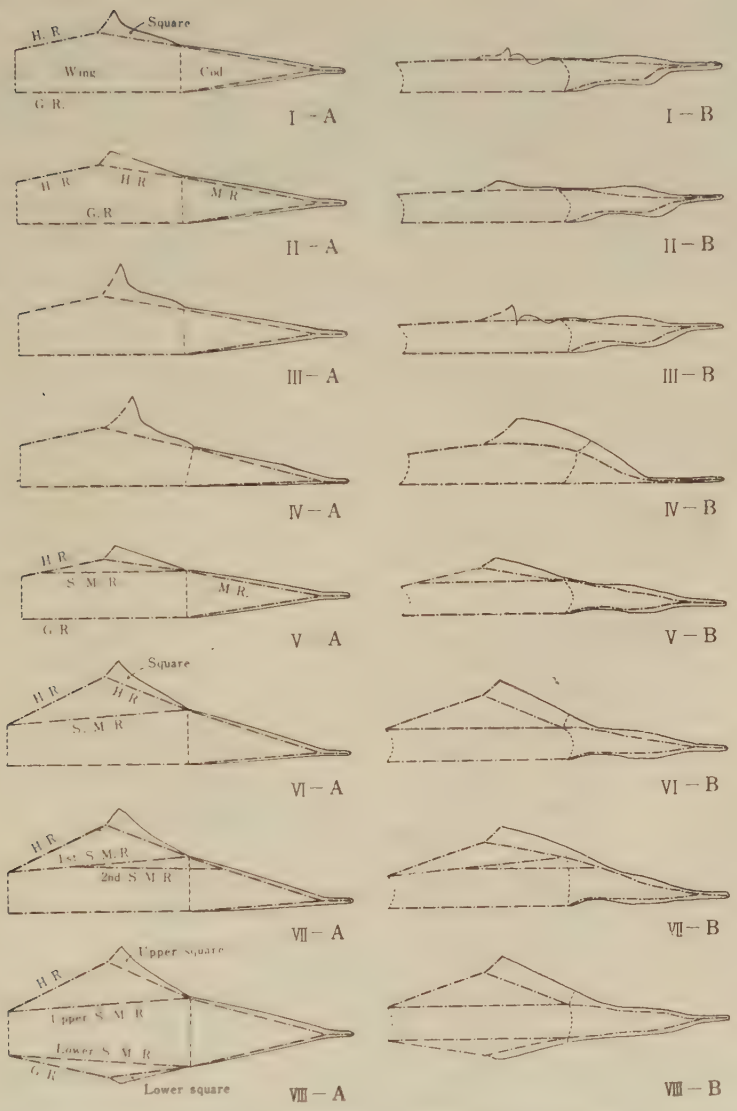


Fig. 2. Conjectural formes of various type nets in the still water A and in the current water (2～3 miles/hour) B.

Note ; Ⅰ～Ⅳ : the ordinaly type net and its modification, *i.e.*, Ⅰ : the ordinary type net, Ⅱ and Ⅲ : ones that the lengths of frontal edge of the square are shorter and longer than those of Ⅰ, respectively. Ⅳ : one that the total length of head rope is longer than those of Ⅰ.

Ⅴ～Ⅷ : ones that the special man ropes to decrease the tension working to head rope of the net-mouth and its neighbourhood are attached to both sides of net-mouth of various type nets, *i.e.*, Ⅴ : the ordinary type net (Ⅱ) with the special man rope, Ⅵ : the $S-I$ type one, Ⅶ : the $S-I$ type one with the 1st and 2nd special man ropes, Ⅷ : the S-II type net, modified the $S-I$ type one, with upper and lower special man ropes.

ヘ　ドローブの長さを全体的にⅠのそれより長くした場合のものである。なおⅤ～Ⅶはいずれも補助力綱を網口附近の特定部に使用した場合であるが，Ⅴは Ⅰの網具そのものに単に口脇部に補助力綱を取り付けただけのもの，Ⅵ（$S-I$型）およびⅦはそれの袖網部を５角型に変形して，それぞれ補助力綱を網口および袋口脇等に取り付けた場合のもの，更にⅧ（$S-II$型）は袖網部を６角型とし，なお且つ底網を添加したもの，上下両口脇にそれぞれ２本の補助力綱を使用した場合のものである。

本実験に供した改良型網具は，上述の原理に基づいて奥袖前端と後端間のヘ　ドローブを補助力綱で絞り，且つ更にその効果を助長させるために奥袖を５角型に設計されたいわゆるS　$-I$型網の基本型ともいうべきもので，その詳細については第３および４図に示したとおりであるが，原理的には　1）網口附近に取り付けられた在来のヘ　ドローブにかかる張力は，補助力綱にその大部分が移行されるため相当減少され，従っ

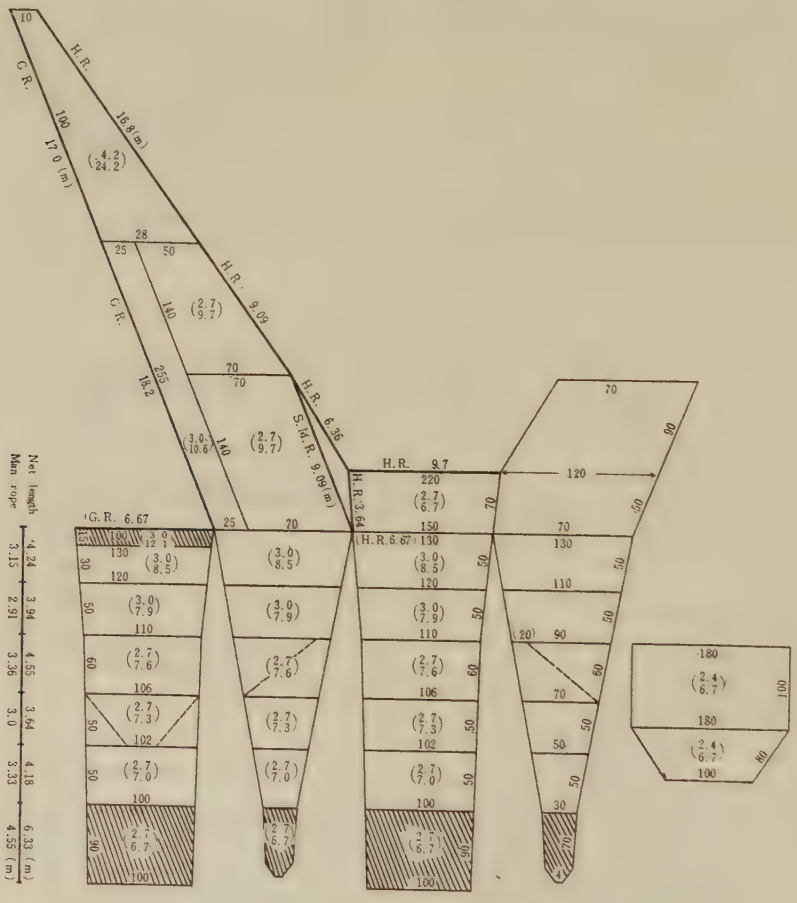


Fig. 3. Gear construction of the Japanese two-boat-type trawl net ($S-I$ type net).
Note ; upper and lower numerals enclosed in brackets indicate diameters of netting cord (manila twine) in mm and mesh size in cm, respectively. Other ones, which are not enclosed in bracket and lacking symbols, show mesh number. Moreover, the parts of oblique lines signify the double cord mesh.

てその部に取り付けられた浮子の効果が激増する．2）奥袖を５角型にしたことで，天井網を流れに対して適当に斜立させ，その部に網地自体による揚力を生ぜしめ，これで網口上部を上方に引き上げるようにしむけた。更に，3）この奥袖の５角型とそれに取り付けられた補助力綱との相互関係から，在来の網具の天井前縁が直線状に設計されていたことで起きる天井前部の曲折垂下，或るいは縮寄せによる波状現象等をあたかも，あらかじめ曳網中に天井前縁が形成する自然の彎曲状に裁断したかの如き効果を生じせしめ，上述の曲折垂下等の現象を防止する。等々の特性を具備し，網口の高さは少なくとも在来の網具のそれの２倍或るいはそれよりやや大きく高められ，底魚は勿論，底層の浮遊魚をも併せ漁獲することもでき，更に必要によっては，上述の天井網部にかかる揚力を利用して，ロープの長さ，或るいは曳網速度を適当に調節することで中層曳操法も容易であり，漁獲能率も在来のものに較べて一段と優れたものと考えられる。

本$S-I$型網は一見林式底曳網[1)2)]と網具の仕上り構造がよく似ており，ややもするとこれと混同されがちであるが，本質的な原理においては両者は全く趣きを異にしたものである。即ち両者共在来の網具より網口の高さを高めるため，網地を補足して嚢口の大きさに比し，網口の大きさを急激に大きく設計されていることは同じであるが，その拡口方法において，林式はカイト等の補助拡網装置を用いて外力により網口を強制的に引き上げ，拡口したのに対し，本網ではそのような装置等は一切使用せずに網口自体がその流体抵抗

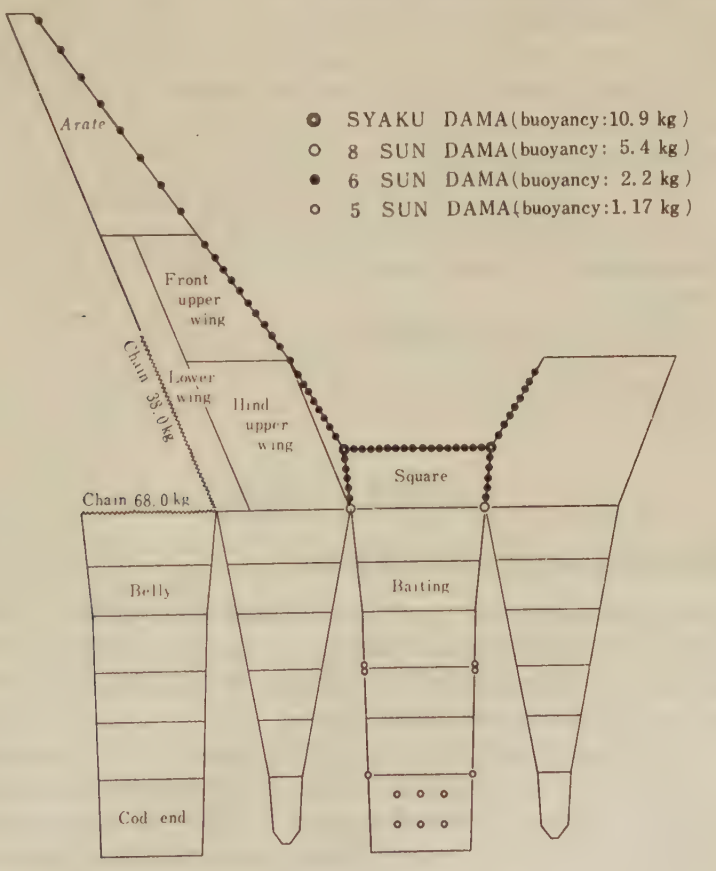


Fig. 4. Standard arrangement of floats and chains.

のみにより自動的に充分拡がり，しかも安定を保持するよう工夫されたものである。従って前者では拡口装置と網具との釣合関係こそ問題であるが，網口附近の構造そのものはそれほど重要な要素とは考えられないが，後者では嚢口の大きさに対する網口の大きさの割合，即ち天井網の傾角ならびに各ヘッドロープ或るいは補助力綱の長さ等の割合を如何に調整するかがキーポイントとなるものであって，単に補助網挿入云々だけでは問題とならず，その調節をあやまると網成りは全くくずれ，天井部の曲折垂下等の悪現象を在来の場合より更に助長させる結果となるだけである。かかる場合には網具の流水抵抗は極端に増大するばかりでなく，時には荷重の増大のあまりワープが切断される等，全く操業不能の事態に陥いる場合も考えられ，莫然と外観的な模倣で事足りたかの如く考えるのは厳につつしまねばならないゆえんである。

実験ならびに模型網

実験は前報[5]と全く同じ方法で，両手木間隔，曳網速度および浮子類の配置，その浮揚力の調整変化等により，網成り特に網口の高さがどのように変化されるか，或るいはそれらによる抵抗変化について，本所備え付けの流水水槽で昭和32年8月から9月にかけて行なわれたものである。

なお供試模型網は田内の相似則[3]に従い次のように作製された。

a）模型網の寸法 λ' と実物網のそれ λ'' との比は1/50とした。

b）網地は実物網のそれがタール染マニラトワイン（比重 $\rho''=1.34$）であるのに対して模型網にはナイロン糸（$\rho'=1.13$）を用い，模型の目合 L' と糸の太さ D' とは実物網のそれら L'' D'' に対して相対応するどの部分でも $L'/L''=D'/D''=0.102$ とした。

c）このように作られた模型と実物網の流速比 V'/V'' は0.207となる。

d）綱類についてはヘッドロープおよびマンロープ（$\rho_1''=5.0$），袖付部グランドロープ（$\rho_1''=1.30$），水戸口付部グランドロープ（$\rho_1''=1.26$）に対して模型ではすべてテビロン糸（$\rho_1'=1.40$）を用い，抵抗を見掛上の重さに比較し無視して綱の太さは，模型のそれ D_1' と実物網のそれ D_1'' との比をそれぞれ0.0933，0.0243，および0.0225とした。

e）浮子についても抵抗を無視し，模型と実物網の相対応する部分の浮力を F'，F'' とするとその比は1.66 $\times 10^{-5}$ となる。

なお模型および実物網の抵抗および沈降力をそれぞれ R'，R'' および W'，W'' とするとその比もこれに従う。

実験結果とその検討

1）両手木間隔の広狭と網成りおよび流水抵抗変化

前報[5]では，在来の網具は両手木間隔が 30 m 附近より狭い範囲では，その広狭により網口の横ならびに高さの方向の拡がりとも互いに逆ではあるが相当増減する。しかし 30 m を超える頃からその広狭は網口にはあまり影響を及ぼさず，網成りおよび網具にかかる抵抗等から総合的に考えると，手木間隔としては30～35 m に保持させるよう操作するのが最適であると述べた。

この網についてはどうであるか，比較の都合上前と同様に，曳網速度2.5ノットで両手木間隔を4～40 m 前後に変えた場合の網成りおよび網口周辺の拡網状況を観測した結果をそれぞれ図版1および第5図に示した。図中二重丸は網口即ち，天井網中央前縁の網底からの高さ，白丸および白三角は口脇即ち，天井前縁両脇端が接合される奥袖の頂点の高さおよびこの点で袖部が切断されたと考えた場合の両袖の水平的な開きを，黒丸および黒三角は嚢口即ち，天井後縁或るいは奥袖後縁と嚢網前縁との縫合部の垂直および水平方向への拡がりを，更に斑丸および斑三角は先，奥両袖の縫合部における両袖の網立ちおよび水平的な開きを示す。

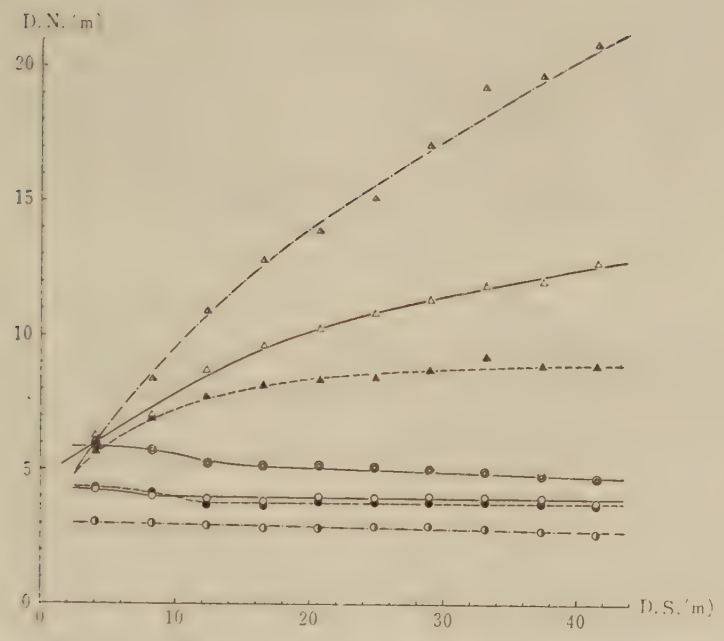


Fig. 5. Deformations of the net-mouth and its neighbourhood [*D. N.*] at various distances between two spreaders attaching to each frontal end of the wings [*D. S.*] under 2.5 smiles/hour towing speed.
Abbreviation, ◎ : the height at the middle of frontal edge of the square part, ○ and △ : the height and horizontal spread at the cutting edges of wings in case that the net is cut transversely at the frontal ends of both square-side, for example. ● and ▲ : the vertical and horizontal dimention of the cross section of the net at the frontal edge of its bag net, ◑ and ◭ : the height and horizontal spread at the frontal edges of the hind wings.

第5図は網口の縦断面の垂直方向（実線）とここと水平方向（破線）への拡がり具合を、在来の網具と比較した結果を示したもので、二重丸は本網具の、掛印は在来の網具のそれをそれぞれ表わす。

次に網具の流水抵抗の変化についても、第7図に在来のものの結果と比較して図示した。即ち図中の丸は本網具の、掛印は在来のものの測定結果である。

これらの諸結果は上述の諸事実と甚だ良好な傾向を示していると考えられるが、細部において吟味するとやや異なった趣きもあるが、両手木間隔を拡げるにつれて変化する網口附近の横方向への拡がり、なおここでは高さの低下の割合は在来の網具のそれに較べ小さく、両網具ともその開きは手木間隔より大きくなるにつれ増大する傾向があらわれる。即ち、両手木間隔が10, 20, 30および40 mと変った時の横方向への拡がりは、在来のものに対してそれぞれ0.6, 1.1, 1.3および1.6割前後狭く，高さはそれぞれ6.5, 7.5, 9.0および11.0割程度高く観測された。

このことは、網口の横方向への拡がりも、単に両袖の開きだけでなく高さの方向への拡がりにも相当関係されるものであり、従って本網具の網口の高さが手木間隔の変化にもかかわらず、ほとんど低下しなかったので、横方向への拡がりにも在来のものの場合の如く大きく拡がらなかったものと考えられる。

次に網具の受ける流水抵抗についても、手木間隔の拡大と共に急激に増加し、その増加の仕方も前報のそ

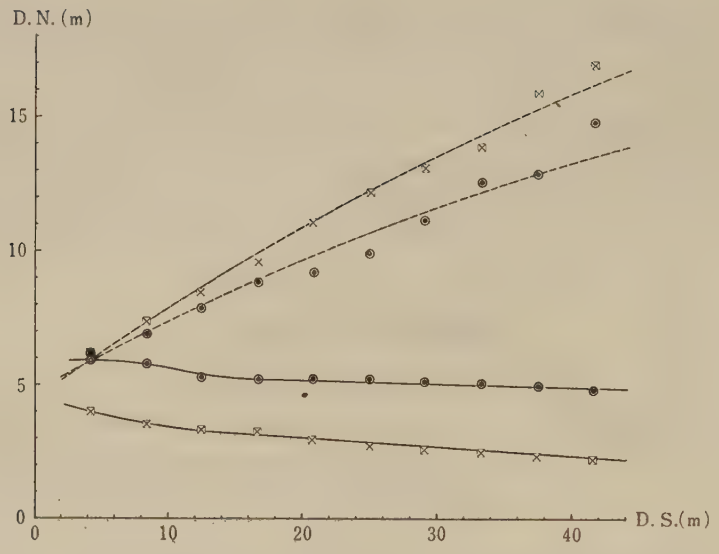


Fig. 6. Comparison between the deformation of the net-mouth of the $S-I$ type net and that of the ordinary type net [$D.\ N.$] at various distances between two spreaders [$D.\ S.$] under 2.5 miles/hour towing speed. Abbreviation, —◎— and ···◎··· : the vertical and horizontal opening of the net-mouth of the $S-I$ type net, —×— and ···×··· : those of the ordinary type net.

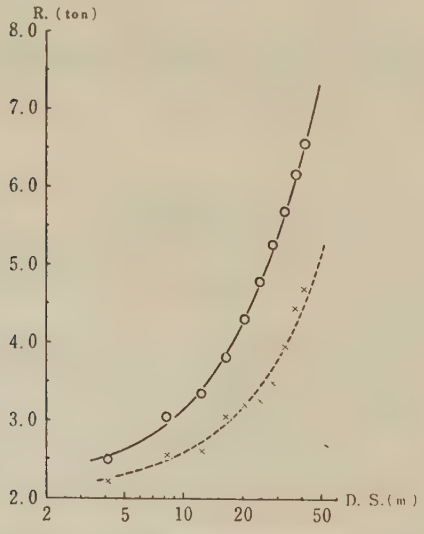


Fig. 7. Relationship between the resistance of the net [R] and the distance between two spreaders attaching to each frontal end of the wings [$D.\ S.$] under 2.5 miles/hour towing speed. Abbreviation, ○ and × : the resistances of the $S-I$ type and the ordinary type net, respectively.

れと全く同様であるが，やはり測定値そのものはこの網のそれが相当大きく，しかも両網具のそれらの差は手木間隔が大きくなるにつれ増大する傾向がみられる．即ち，手木間隔が 10，20，30 および 40 m における本網の抵抗値は在来のものに比べてそれぞれ 2.0，3.5，4.0，および 4.5 割大きく観測された。

このことと，上述の第6図の結果を併せ考えると，この網の網口断面積そのものも在来のものに較べて手木間隔の広狭の影響を蒙る程度が極めて少なく，常にほぼ定状をなしているということができる。

以上網部については在来の網具に較べ，本網具は異なった特質がみられたのであるが，純力学的な総合的見地よりすれば，この網でもやはり両手木間隔としては前と同様 30 m 前後で操業されるのが最適であると考えられる。

2）曳網速度変化による網成りおよび抵抗

このことについては，前報[5]の網具の場合には，曳網速度が2ノット附近よりおそい範囲ではその速度の遅速により網口の高さは相当高く又低くなるが，2ノット以上になると速度の大きさにかかわらずほぼ一定となり，静止時の約半分の高さに落ちつく．しかして，横方向への拡がりは常に速度には無関係にほぼ定状を保っている．また抵抗は曳網速度が1～4ノットの範囲内では，速度の自乗にほぼ比例して増加することを述べた。

この網についても，前報と同様両手木間隔を 33.2 m とし，曳網速度を0～4ノット前後にわたり種々変化させた場合の網成りならびに，その抵抗変化について観測した。結果は図版2ならびに第8，9および10図（図中の記号はそれぞれ第5，6，7図に同じ）に示したとおりで，前報の結果とはやや趣きを異にし，網

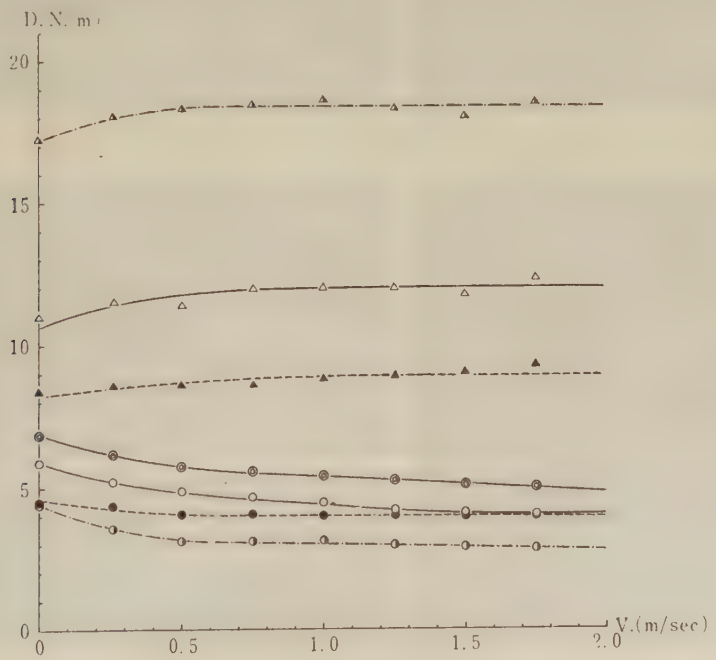


Fig. 8. Deformation of the net-mouth and its neighbourhood [*D. N.*] at various towing velocities [*V*] under 33.2 m in the distance between two spreaders.
Note ; Symbols are the same as Fig. 5.

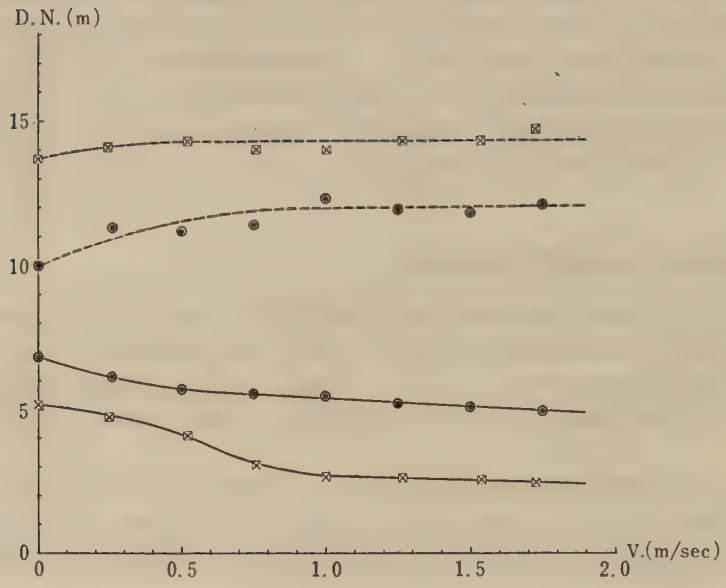


Fig. 9. Comparison between the deformation of the net-mouth of the $S-I$ type net and that of the ordinary type net [$D.\ N.$] at various towing velocities [V] under 33.2 m in the distance between two spreaders.
Note ; Symbols are the same as Fig. 6.

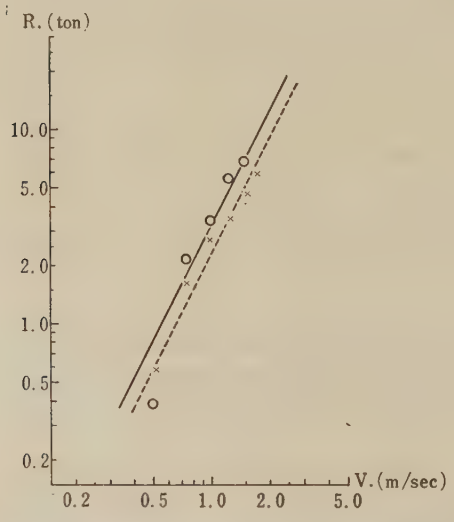
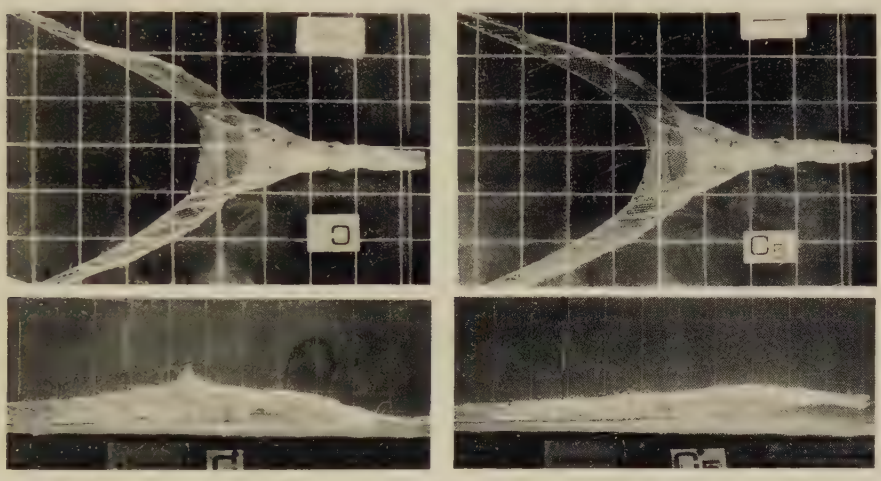


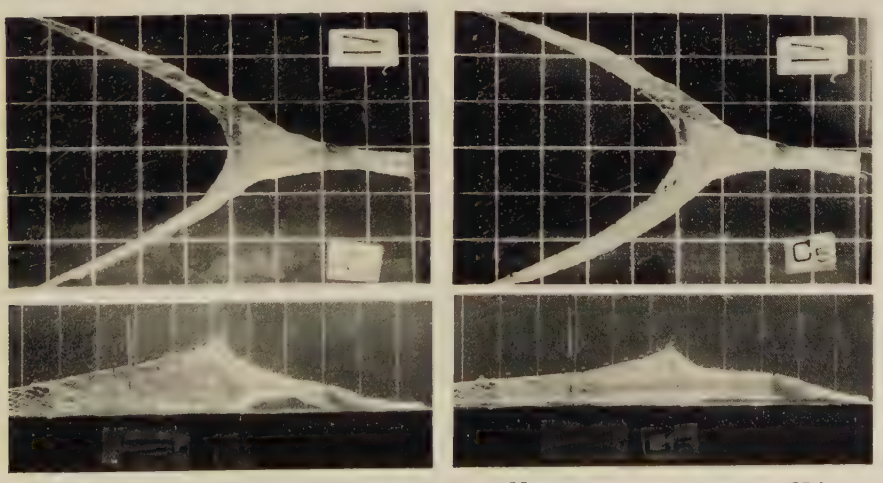
Fig. 10. Relationship between the resistance of the net [R] and the towing velocity [V] under 33.2 m in the distance between two spreaders.
Note ; Symbols are the same as Fig. 7.

口附近の横方向への拡がりは前報と同様，速度にかかわりなくほぼ定状をなしているが，速度増加にともなう高さの低下の割合は，極めてわずかづつで，前報の如き急激な変化はみられない。しかもその網口の高さは，在来の場合に較べ常に大きく観測されたが，横方向へは逆に狭くなっている。即ち曳網速度が2.5ノットで在来の網具の網口の高さは2.6 mであったのに対して，この網では5.3 mで約2倍，横方向への拡がりは前者は14.3 mであったのに対して，後者では12.0 mで1.6割近く狭く観測された。なお袖網および曩口附近の速度変化による網成り変化はほとんど認められないが，これらの網立ちはやはり在来のものに較べると，2.5ノット時で，それぞれ1.5および2倍前後高くなっている.

抵抗については，本実験の1～4ノットの範囲内では速度の自乗にほぼ比例することは前報の結果と同じ



〔A〕 The Ordinary Type Net 〔B〕



〔A〕 The $S-I$ Type Net 〔B〕

Fig. 11. Comparison of the forms between the ordinary type net and the $S-I$ type one at 0 and 2.5 miles/hour towing speed under 33.2 m in the distance between two spreaders, respectively.
Note ; 〔A〕 and 〔B〕 : the top- and side photographs of the ordinary type and the $S-I$ type one at 0 and 2.5 miles/hour towing speed.

であるが，測定値は，網地の総使用量においては前報のそれとほぼ変りないにもかかわらず，前報のものより約1.4倍前後大きく観測された。このことは本網具が在来のものより網口の高さにおいて高いというだけでなく，その断面積そのものも相当大きいことを意味する。

第11図は在来の網具と本網具の静止時，ならびに曳網時（速度2.5ノット）の網成り状態を比較したもので，在来の網具では静止時には比較的良好な網成りを示しているが，曳網されると極めて不良となり，特に天井網前部が大きく低下するばかりでなく，曲折垂下，或るいは波状現象を呈し，網口の高さの方向への拡がりを著しく阻害する（この現象は速度が速くなるほど著しくなる）。これに対し，本網具では曳網中でも天井網部はほぼ理想状態をなし，全体的に網立ちも良く，非常に良い網成りをなしている。このことは速度が更に増大されてもほぼ変りなく，先に予期したように補助力綱にヘッドロープ等にかかっていた張力の大部分が移行され，その部の浮子の効果が増したことは勿論であるが，それにも増して天井網および袖網上部等に揚力が働き，これが網口およびその附近の各部の低下を防止したものと考えられる。

以上の諸事実から明らかなように，網口の大きさについて云々する場合には，網口前端だけの大きさだけでなく，その前後の網成り状態を総合的にあわせ考えなければ意義はなく，いたずらに前端だけを極端に拡げても網成りはくずれ，漁獲性能も低下すると思われる（例えば前述の両網具の網口前端そのものの高さの比は1：2の割合であるが，前者の天井網の曲折垂下等を加味するならば両者の比は1：2.5以上となる）。

なお前報でも在来の網具では，網成りならびに抵抗等総合的見地から，2.5ノット程度で操業されるのが最も当を得たものであると述べたが，この網でも，これと同様，曳網速度としてはやはり2.5ノット前後が妥当な速度であるといえる。

3）浮子の配備と浮揚力変化による網成り変化

前報[5]では，在来の網具はその装備する浮子類の浮揚力を多少増減しても，網口の高さはあまり変化しない即ち一定以上の浮揚力の増強はいたずらに網具全体を底面から浮上させるだけの効果で，網口の高さは高まらず，既にそれは構成法で定まっている。従って浮子としては投網初期網口その他がもつれず，網成りが整う程度の最少量を使用するのが得策であると述べた。

この網では，その構造がそれとは多少異なるので，比較の都合上，曳網速度2.5ノット，両手木間隔33.2 mとし，網口附近の網立に関係が深いと考えられる各部の浮揚力，或るいはその配置をいろいろに変えて，網成り，特に網立ちへの影響について観測した。

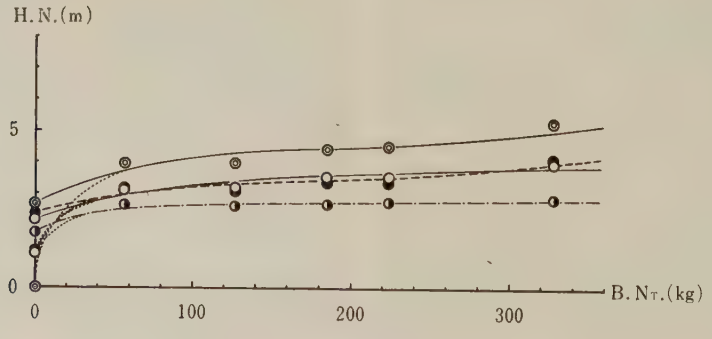


Fig. 12. Height of the net-mouth and its neighbourhood [$H.\ N.$] at various buoyancies of all floats attaching to each part of the net [$B.\ N_T$] under 2.5 miles/hour towing speed and 33.2 m in the distance between two spreaders.
Note ; See Table 1 which showed various buoyancys of floats attaching to each part of the net, and symbols are the same as Fig. 5.

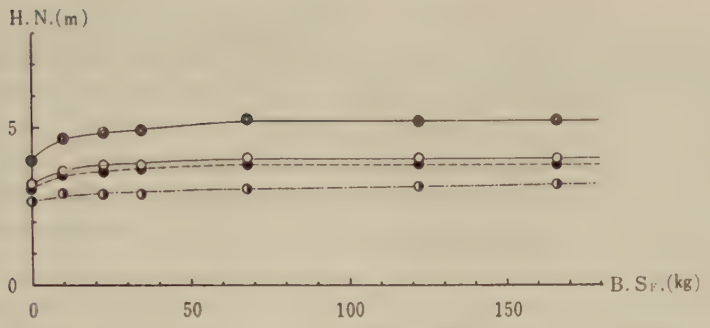


Fig. 13. Height of the net-mouth and its neighbourhood [$H.\ N.$] at various buoyancies of only the float attaching to frontal head rope of square [$B.\ S_F$] under 2.5 miles/hour towing speed and 33.2 m in the distance between two spreaders.
Note ; See Table 2 which showed to arrangement of floats attaching to the other parts of the net, and symbols are the same as Fig. 5.

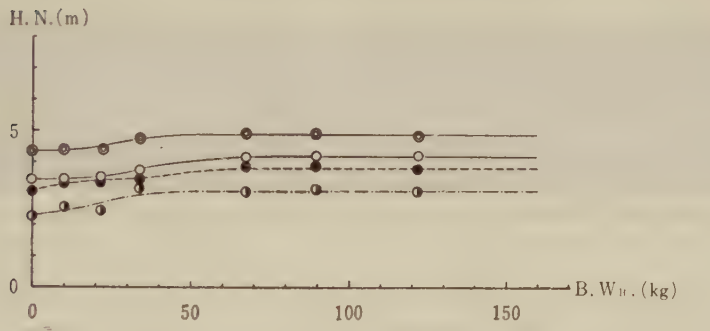


Fig. 14. Height of the net-mouth and its neighbourhood [$H.\ N.$] at various buoyancies of only the float attaching to head rope of hind wing [$B.W_H$] under 2.5 miles/hour towing speed and 33.2 m in the distance between two spreaders.
Note ; See Table 3 which showed to arrangement of floats attaching to the other parts of the net, and symbols are the same as Fig. 5.

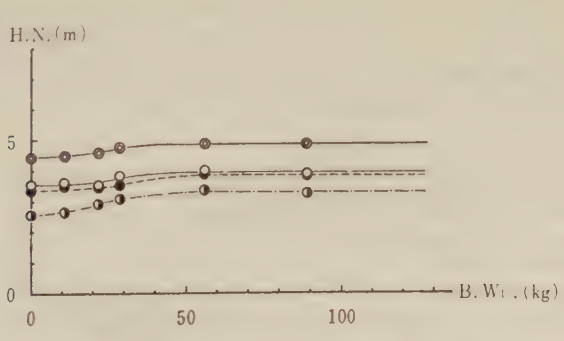


Fig. 15. Height of the net-mouth and its neighbourhood[$H.\ N.$] at various buoyancies of only the float attaching to head rope of front wing [$B.\ W_F$] under 2.5 miles/hour towing speed and 33.2 m in the distance between two spreaders.
Note ; See Table 4 which showed to arrangement of floats attaching to the other parts of the net, and symbols are the same as Fig. 5.

第12図は袖および天井網等各部の浮揚力を同じ割合で全体的に変化させた場合（第1表），第13図は天井網前縁のみの浮揚力は変化させるが，その他の各部は変化させない場合（第2表），同様に第14および15図は奥袖（第3表）および先袖（第4表）のみの浮揚力をそれぞれ変化させた場合の口脇，網口および囊口等の網立ちを示したものである（図中の記号は第5図に同じ）。

結果は前報の場合に較べて多少の効果がみられるようであるが，特別な場合を除き，浮揚力の増減，或るいはその配置の如何をとわず，やはり網口の拡がりへの影響はあまりなく，この網でも網口の高さは構造上既に決まっており，浮子としては前述の如く投網初期の網成りがくずれない最少量のものを使用するのが得策であるといえる。

Table 1. Arrangement of floats attaching to the net.

No.	Buoyancies of floats attaching to total head ropes	Buoyancies of floats attaching to each head rope			
		Frontal H. R. of square	H. R. of hind wing (one side)	H. R. of front wing (one side)	H. R. of *arate* (one side)
1	0. kg	0. kg	0. kg	0. kg	0. kg
2	56.9	11.7	10.9	5.85	5.85
3	127.2	23.4	22.6	11.7	17.6
4	185.0	35.2	33.9	23.4	17.6
5	224.0	57.0	45.6	23.4	17.6
6	328.0	89.8	78.3	23.4	17.6

Buoyancies of floats attaching to man rope (one side) and cod end; 3.5 and 7.0 kg in 5 *Sun Dama*, respectively. Weights of chains attaching to ground ropes of hind wing (one side) and belly; 38.0 and 68.0 kg, respectively.

Table 2. Arrangement of float attaching to the net.

Part	Buoyancy (size and number of float)
Frontal H. R. of square	0 ～ 170 kg
H. R. of hind wing (one side)	45.6 kg (10 and 8 *Sun Dama* : each 1, 6 *Sun Dama* : 13)
H. R. of front wing (one side)	23.4 kg (6 *Sun Dama* : 11)
H. R. of *arate* (one side)	17.6 kg (6 *Sun Dama* : 8)

Buoyancies of floats attaching to man rope (one side) and cod end; 3.5 and 7.0 kg in 5 *Sun Dama*, respectively. Weights of chains attaching to ground ropes of hind wing (one side) and belly; 38.0 and 68.0 kg, respectively.

Table 3. Arrangement of float attaching to the net.

Part	Buoyancy (size and number of float)
H. R. of hind wing (one side)	0 ～ 122 kg
H. R. of front wing (one side)	23.4 kg (6 *Sun Dama* : 11)
Frontal H. R. of square	35.2 kg (6 *Sun Dama* : 16)
H. R. of *arate* (one side)	17.6 kg (6 *Sun Dama* : 8)

Buoyancies of floats attaching to man rope (one side) and cod end; 3.5 and 7.0 kg in 5 *Sun Dama*, respectively. Weights of chains attaching to ground rope of hind wing (one side) and belly; 38.0 and 68.0 kg, respectively.

Table 4. Arrangement of float attaching to the net.

Part	Buoyancy (size and number of float)
H. R. of front wing (one side)	0～90 kg
Frontal H. R. of square	35.2 kg (6 *Sun Dama* : 16)
H. R. of hind wing (one side)	45.6 kg (10 and 8 *Sun Dama* : each 1, 6 *Sun Dama* : 13)
H. R. of *arate* (one side)	17.6 kg (6 *Sun Dama* : 8)

Buoyancies of floats attaching to man rope (one side) and cod end; 3.5 and 7.0 kg in 5 *Sun Dama*, respectively. Weights of chains attaching to ground rope of hind wing (one side) and belly; 38.0 and 68.0 kg, respectively.

先に業室[4]は浮子を全く装着しない裸網でもその網高さは絶対零ではなく相当量あり，網口で約0.6 m 前後と報告したが，前報の結果では天井前部が底面に吹きつけられて網口の高さは零であり，これらの違いは両網具の構造上の相違によるものであろうと述べた。

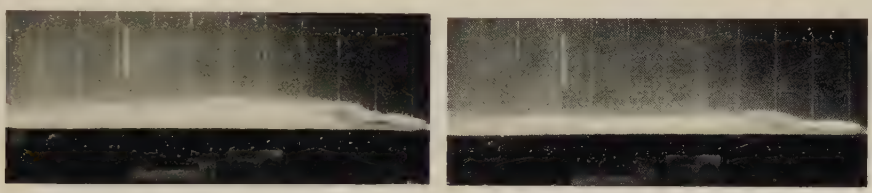


Fig. 16. Comparison of net-heights of one and the same net without float when it is worked through different management.
Note ; *A* : side photographs of the net towed at 2.5 miles/hour towing speed, after it is set in the current water under 33.2 m in the distance between two spreaders.
B : one of the net towed at 2.5 miles/hour towing speed, after it is set in the still water under 33.2 m in the distance between two spreaders.

第12および16図において浮揚力が零，即ち裸網のものの測定値が２通り示されているが，これは網具の操作法を異にした場合の結果で，実線およびA図は流水中に網を投入した時のもの，破線およびB図で示されたものは流れを静止状態におき投網，網成りの安定を待って流れを起こした場合で，この網では浮子を全く装着しなくても，その操作法の如何によっては網口は相当量拡がった。

これは前者が投網と同時に曳網される結果となるので，流水により天井部に揚力が働き網口が拡がるのに対し，後者ではヘッド部が自重により一端底面に達した後流れが当たることになるので，天井部に揚力は働かず，逆に底面に吹きつけられる結果となるので，このような相違がみられたものである。

そこで前報において，在来の網具では操作法の如何にかかわらず，裸網では，網口の高さは零，前述の業室のそれの0.6 m 前後に対し，この網の2.5 m 前後の網高さは（この数値は在来の網具の理想時の網高さに相当する），天井網部等上網部にかかる揚力が如何に大きく，また網具の設計の可否が如何に重要な問題としてとりあつかわれるべきことであるかが明らかである。

従って，この網では浮子をそれほど多く装着しない場合でも，上網部に生じる揚力で網口附近のグランド部が底面から浮上する傾向がみられ，ややもすると網全体が飛行状態をなして曳網されることになる。

このことは時としては後述するように，浮上魚群を対象とする中層曳操法を行なうには極めて便利であるが，あくまで底魚を主体として操業しなければならない現況においては，これまで一般に払われていたヘッド部の浮子への関心を，この網では逆にグランド部の沈降力の増減に払い，網の浮上を防止することに留意

[illegible]

即ち、このゲランド部の沈降力の調整は、両翼端綱、引綱速度、[illegible]

[illegible]

以上総合すると、本改良型網は従来の網具に較べ、網成りは不良、網口の高さにおいては特に劣るが、反面よりうまでもなく、成る程度、漁獲を増加できる。又、網具の取扱いについては従来の網具と同様な操作ができる。しかし、本網具の対象とする魚種は極めて多く、従ってそれぞれの特性も各異なるため、[illegible]

[illegible]

以西底曳網漁の対象とする重要魚種の動静と これに対する漁具漁法的考察

[illegible]

左右するものとして極めて注目されているものである。

これらの各魚種、動態、即ちそれぞれ、回遊経路、[illegible]があり、成群構造については、その一部の問題についてではあるが、[illegible]。しかしながら、これらはいずれも純生物学的見地からのものが主体であり、網具の設計、或いはその操作上の指針とする資料としては不充分である。

そこで、ここでは主として最近、[illegible]、或いは[illegible]による操業の比較結果等諸々の体験報告から、上述のキグチ、エビ等[illegible]漁具漁法的見地から検討し、これに対する[illegible]等について、[illegible]。

キグチ漁について

本種は東支那海東部、[illegible]、長崎、長海、[illegible]。漁獲量は[illegible]。[illegible]ということで、本底曳漁業としては最も重要視されている魚種である。

これら[illegible]、或いは産卵、[illegible]については、[illegible]。

[illegible]は東海北部の広大な海域で濃密、且つ大群が漁獲されると述べている。

これら、各漁期、漁場等の成群構造を知ることは、[illegible]。これに関する[illegible]。

Fig. 17. Chart showing the estimated migration of yellow croaker (*Pseudosciaena manchurica*) caught in the East China and the Yellow Sea.

Abbreviation, ⇉⇉ : migration route (figures show the date in month), ⬭ : main fishing area, ▨ : area passing winter, ▨ : spawning ground. (From OKADA)

験報告から推測すると，次の如く，漁期，昼夜，或るいは潮汐等の変化により成群構造にも変化がみられ，使用網具としても，或る時には平面的な在来の網具の方が，時には反対に立体的な改良型網具の方に好結果がみられる等，状況如何でそれらの価値は全く主客転倒し，一概に網口の高さの問題等で漁具の優劣を論ずることはできないようである。

即ち季節的には3月下旬から4月中旬にかけ，農林324，325，334，および335漁区を中心に操業される春キグチ（主として産卵前の魚群）においては，魚群が極めて濃密で且つ海底から10～15 m 層にまで大きく盛り上がった群構造を形成するのが特徴であるのに対し，7月から8月下旬にかけて，315，316，324，325，334および335漁区周辺にわたる広大な海域で漁獲される夏キグチ（主に産卵後の魚群）では，魚群もあまり濃密ではなく，また春キグチのような大きく盛り上がるような群形成はみられず，比較的底層に停滞しているようで，魚探による感応もあまり明瞭でない。更に9月から11月にかけて323，324，325，315，305，306，296，297漁区等にわたって漁獲される秋キグチに至っては，極めて底層もしくは全く海底に接して，平面的には大きく且つ濃密な群形成をなしているものと思われ，漁獲は極めて大であるが，魚探感応は全く認めら

れないようである。

このことは本改良型と在来の網具との漁獲成績の比較でも明確にうかがわれ，春キグチにおいては，改良型の漁獲が在来の網具より飛躍的に大であるのに対し，夏キグチでは，両網具によるそれらはあまり明確には現われないが，やや改良型に優位さが感じられ，秋キグチにおいては，特異な要因即ち，この期の前半はクラゲの大発生期に当り，これが海底から4～5m層のところの比較的低層部にまで濃密に分布し，改良網を使用すると，時には大挙入網し，しばしば操業不能の事態が生じることにも関係するが，この時期には逆に網口の低い在来の網具の方が漁獲成績も良好であり，更にこれより，より水平的高性能な網具を用いた場合には一段と好結果が得られたと報告されている。なお，冬期の状況については，近年来，大多数の漁船が後述のエビ漁に操業を移行したので，全く明らかでないが，秋型から直線的に春型へ，もしくはその過程でピークを画き春型へと移行し，その後半期にはほぼ春型のものに近い群構造をなす模様である。

最首等[10]によると，キグチ群は昼間底層に停滞し，夜間浮上すると述べている。第18図は魚探感応による

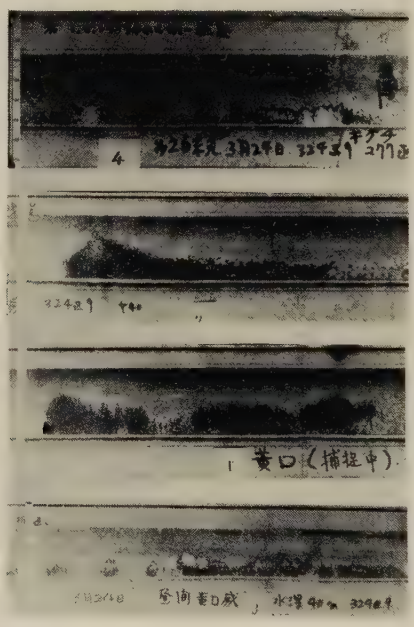


Fig. 18. Photographs showing a series of reflections of a school of yellow croaker (*Pseudosciaena manchurica*), caught in spring, caught through the fish echo finder.
Note ; 〔*A*〕: typical shape of a school of yellow croaker in spring, and each reflection showed in *1*, *2* and *3* is that of one and the same school of the fish caught on different course of the boat, respectively.
〔*B*〕, 〔*C*〕 and 〔*D*〕: reflections of a school of the fish at night, at early dawn and in the daytime, respectively.

春キグチの代表的な成群構造，ならびにその昼夜の変化を比較したもので，〔A〕は同一群をそれぞれ別の三方向からキャッチした場合のもの，〔B〕〔C〕〔D〕は夜間，未明時および昼間における魚群体の感応である。これらの結果では夜間は極めて高層まで湧き立っていた群構造が，夜明けと共に徐々に沈下して行く傾向がみられるが，昼間でもなお相当高い盛り上がりの構造をなし，しかも昼夜を問わず魚群体の主力はごく低層附近にみられ，上述の最首等のいう群の浮上というよりはむしろ底層を基とした魚群体の拡散と考え

るのが妥当のようである。従って漁具漁法的にもあくまでその着眼点を海底，もしくはその近辺の底層におくべきで，これを無視したかの如き中層曳漁法に走るのは厳に注意を要すると考えられる。なお，夏キグチにおいては，この昼夜による拡散現象の違いは，それほど著しくはなく，秋キグチに至っては全く認められないようである。

次に，成群構造変化は潮汐によってもみられるようで，大潮時には一般に群は拡散し，小潮時には群密度も高く，しかもそれがごく底層附近にあるとみえ，在来の網具でも漁獲は非常に多いといわれている。

このようにキグチの成群構造は各種の要因により極めて複雑に変わり，本漁における網具としては，これといった決め手の網型というべきものはなく，春から夏のキグチ漁には改良型網具または，これより更に網口の立体的に大きい網具を考案使用するのが効果的であると考えられるのに対し，秋キグチ漁においては，網口は高さの方向へよりも水平的に大きい網具を使用した方が逆に効果が上げられるようで，平面的な在来の網具，更には，より水平的な網口の大きい網具を工夫して操業すべきであることはいうまでもなく，両船間隔，曳網速度等網具の調整上の問題も充分考慮し，最も効果あらしめるよう調整する等，合理的な操業法を考えなければならない。

コウライエビ漁について

本種は主として黄海以北に分布し，戦前はもっぱらトロール船のみの冬期における好対象魚とされ，底曳網では漁獲できず対象外のものとみなされていたのであるが，その後漁具漁法の進歩と共に，わずかづつではあるが黄海北部漁場で漁獲されるようになっていた。ところが33年暮から翌年春にかけて，未曽有のエビの大群発生がみられると時を同じうして，網具としてもそれまでいろいろ改良工夫を重ねられていた本改良型網具が操業的にもようやく実用的段階に達し，普通の底曳網では漁獲不能とされていた黄海中，南部の海域でもこれを使用することで，大成果が上げられ，たちまちにしてこれが全業界に普及し，一躍本種も底曳網漁の冬期の好対象としての脚光を浴び，その後更に本網具の改良進歩と共に最近では逆にトロール船，その他の追従を全くゆるさず，漁獲総量においては前述のキグチのそれには相当劣るが，経済的比重はむしろ逆で，底曳船の冬期の漁業形態を一変せしめるに至った最重要種である。

本種の回遊経路およびその漁期漁場について，笠原[6]，岡田[7]，木部崎[8]，等は第19図にみられるように，5月頃，主として渤海，遼東半島南岸で孵化，成長したものが，9，10月頃同海域を移動し始め，11月頃山東高角沖の136漁区附近に姿を現わす。12月頃から操業が始まるが，この頃の主漁場は，山東沖合およびその南にあり，エビ群は密集している。1月には更に南下し，南限33°～40°N線に至り，この海域で越冬するが，群は散在状態である。2月から北上を始め，3月にはやや濃密群が137，127，から150，140漁区にかけた海域に集まり，よい漁場をつくる。更にこの群は4月には山東高角を廻り，5月から6月には全部渤海内に入る。従って漁期は12月～4月の短期間内で，越冬期には一般の魚と反対に散在し，南下移動と北上移動の際に非常に密集し，よく漁獲されると述べている。

以上，このエビ魚群も漁期，漁場で幾分その成群構造を異にする感があるが，これについて更に深く魚探の記録，その他による現場当事者の報告より検討すると，漁期的には　1）12月上旬から下旬，時により1月上旬に及ぶ南下移動時のエビ群では，その群構造は海底もしくはごく低層部に平面的な濃密群を形成するが，2）1月上旬もしくは中旬から3月上旬頃の越冬期および，北上移動前期のそれは一般に海底より浮上気味で，低層からごく高層にかけての分散型，或るいはごく高層もしくは海面附近を浮上密集する型等，主に立体的に比較的濃密群を形成するのが特徴である。更に，3）3月下旬から4月上旬の北上移動の後期のものではほぼ前二者の中間型（やや前者に近い型）の濃密群を型成する等，3つの型に類別でき，それぞれ漁具，漁法的にも異なった特徴がみられるようである。しかしながら，上述の群変化は漁期的変化とみるよりはむしろ海況の相違からの漁場的変化とするのが至当のようで，35°—30′ N 線附近を境にその以

Fig. 19. Chart showing the estimated migration of Yellow Sea prawn (*Penaeus orientalis*) caught in the Yellow Sea.
Note ; Symbols are the same as Fig. 17. (From OKADA)

北と以南の漁場で成群構造上ほぼ２分でき，それぞれ特異性が認められる。即ち，農林148，138，128漁区以北の漁場は水深は比較的浅く，海水は透明度が大であり，ここでのエビ群は海底もしくは底層に平面的な濃密群を形成するのが特徴であるが（主として南下移動群，ならびに北上移動終期の魚群がこれに該当），35°—30′ N 線以南の140，150，331，332，333 漁区およびその周辺の漁場は比較的水深が深く，かつ海底は非常に泥深い。また全般的にも水の透明度はきわめて悪い状況を呈し，エビ群は常に浮上気味で，上述の越冬期および北上移動前期のそれで述べた如く，立体的分布をなすのが特徴である。従って前述の如き新旧両網での操業結果を比較対照すれば，45°—30′ N線以北の漁場における南下移動群に対しては，従来の網具で十分漁獲は可能であり，効率的にもややこの網の場合が勝っているようであるが，以南の漁場では，改良型網の独断場で，時により本網具を海底より浮上させ，いわゆる中層曳操法を行うことで，更に好成績が得られる模様である。なお，前述の以北漁場でも北上群に対しては在来の網口の高さの低いものより，改良型の高いものを使用する方が，やや好成績が得られるといわれている。

最首等[10]によると，エビ群の昼夜による垂直移動は認められないと述べている。しかしこれは以前黄海北部の漁場を主体として操業されたものより判断されたものと思われ，最近の魚探の記録，或るいは現場当時者等の所見を参照に検討すると，なるほど上述の以北漁場の南下移動群では上述のとおりそれはほとんど認められないようであるが，以南漁場の越冬期および北上前期の魚群では，明らかに，極めて大きい垂直移動が認められ，以北の漁場でも北上群ではかなりの変化がみられるようである。第20図は35°—30′ N線以南の各漁区における北上移動初期のエビ群の成群構造，および昼夜による垂直移動変化の模様を比較示したもの

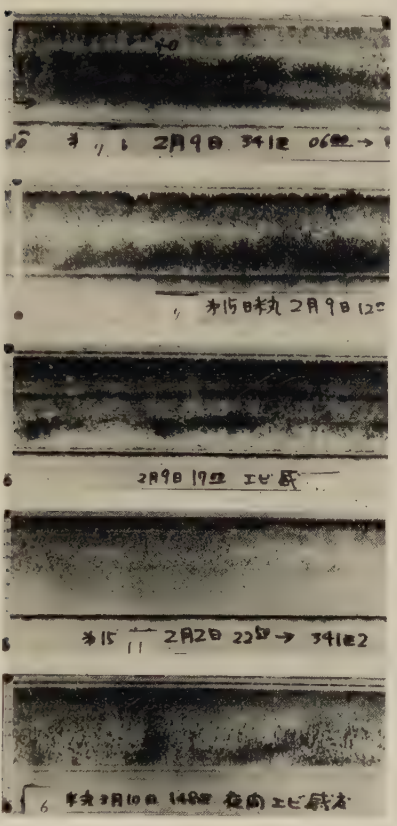


Fig. 20. Photographs showing a series of reflection of a school of Yellow Sea prawn (*Penaeus orientalis*), caught in the fishing ground south of 45°-30′ N lat. caught through the fish echo finder.
Noet ; 〔*A*〕, 〔*B*〕, 〔*C*〕 and 〔*D*〕 : reflections of a school of Yellow Sea prawn at early dawn, in the daytime, at dusk and at night of the early fishing season of its fishing ground, respectively. 〔*E*〕 : that at night of the latter stage of it.

であるが，夜間は極めて上層，或るいは海面附近まで浮上するのに対して，昼間は比較的低層に沈下する。しかして，漁場が北に進むにつれて魚群の分布層は昼，夜共にやや低下する傾向がみられる。

以上述べたことから判るように，エビの成群構造は，前述のキグチに較べると極めて短漁期間において，漁場，或るいはその時期，昼夜の別等で極めて大きく変化する．従って漁具としても，キグチの場合と同様，特定型というべきものはなく，南下群に対しては平面的に網口の大きい在来の網具が有利であり，越冬ならびに北上群に対しては改良型もしくは，更に網口を高く改良された *S-II* 型（第２図参照）等の網具に絶対性があり，夜間においては中層曳操法もあながち無意味ではなく，時としては極めて効果的な方法で一考に値する問題と考えられる

従って理想としては，これらを，適当に使い分けることであるが，そのようなことは，キグチ群の如く長期的な変化の場合は別として，本種の如く短期間内のめまぐるしい変化を示すものでは，実際問題としては極めて困難であり，キグチ群からみると総体に垂直的な分布層も厚く，分布が平面的な南下群でも網口の高い網具を使用しても，特別に操業上支障があるとは考えられないから，エビ漁としては，網口のできるだけ高いもので，操業するのが得策と考えられる。

その他の重要魚種について

前述のキグチ，エビ類の他に，漁獲量においてはこれらとは問題にならないが，東海，黄海の全域に分布し，主としてキグチ漁の場つなぎ，或るいは補足用として二義的ではあるが，本底曳網漁業で重要視されている魚種に，シログチ，タチ，ハモ，タイ，およびカレイ類がある。

これらの成群構造については，あまり明らかでないが，既往の文献，或るいは現場当事者等の所見を総合すると，次の如く，魚種によっては漁期，漁場，或るいはその他の要因によって変化し，或る種のものはほとんど変りがない等，それぞれ異なり，漁具，漁法的にも極めて興味あることと考えられる。

即ち，これらの内でも特に著しい変化のみられるものは，タチウオで，最首等[10]は，この種は成長段階で，群構造の違いがみられることを指摘し，小タチの時期には“昼間底層に停滞し，夜間浮上する”が，大ダチになると逆に“夜間底層に停滞し，昼間浮上する”と述べ，また真子[8]は，冬期済州島西方で漁獲されるものは“後者即ち，昼間浮上型”であるのに対し，夏期の産卵期に大陸沿岸で漁獲されるものは“前者即ち，夜間浮上型”であると述べている。なおタチは前述のキグチにみられた如く，潮汐の変化にも関係があるもようで，大潮時には浮上するので，網口の低い在来の網具では漁獲が少なく，この場合改良型網具が要求され，小潮時には魚群は海底附近に沈下し，在来の網具でも漁獲は良好とされている。

次に，シログチでも，最首等は成長段階による差異を指摘し，小型魚では昼夜による垂直分布の違いはないが，大型魚では時により昼間は底層に停滞し，夜間浮上するものもあり，あるいは昼夜の違いを示さない場合等，いわめる小型魚との混合型をなすと述べている。

ハモでは特に成長段階による差は認められないようであるが，昼夜による変化が認められ，昼間は底層に集中して停滞するが，夜間は拡散且つ浮上するといわれている。

更にタイ類では，黄海以北のマダイは昼夜による分布変化がみられることもあるようであるが，東海南部のレンコダイは全く変化はみられないようで，同じくカレイ類と共に，常に底層若しくは海底に接した平面的な群形成をなしているものと考えられる。

以上これらの各魚種においてもやはり，それぞれ魚種特有の成群構造の変化がみられ，適用すべき網具も，それぞれまちまちの要素のものが要求されることは，前述のキグチおよびエビ漁の場合と同様であるが，概してタチウオおよびハモでは網口の高い改良型，シログチ，タイ類およびカレイ類では，どちらかといえば，網口の高さは低くとも，水平的に巾広く，しかも曳網速度の速い在来の網具に好成果が得られるようである。

以上の諸結果を総括して考えると，本底曳網の対象となる重要魚類は，各魚種により，またさまざまな状況下において，きわめて複雑な成群構造を呈していることは，前述のとおりである。従って漁具としても，それぞれの魚種，それぞれの状況に応じて，平面的，あるいは立体的な構造のもの，更に又，底曳網のみでなく，中層曳漁法による操業など，その場に応じた合理的な方法を用いるべきである。しかしながら，その成群構造の変化にある程度の余裕や期間がある場合は別として，昼と夜とでめまぐるしく変化する等の場合，いちいちその場に即応する漁具を数種類常備し，使用することはあくまでも理想であって，現実としては全く困難である。

今後の課題は，その理想をいかに現実のものにするかにかかっている。それには網口の高さをより高くす

ることだけでなく，網口の高低自在，しかも底曳，中層曳兼用のいわゆる調整式網具の案出にある。

これについては後日改めて順を追い，より理想に近い考案および改良結果を報告することとし，ここではとりあえず応急的手段として本改良型網にわずか手を加えるだけで比較的簡単に，それぞれの場合に或る程度，効果的に即応する方法のみについて二，三所見を述べる。即ち，前述の網具の構造，或るいは力学的諸検討結果からもわかることであるが，

（1）網具改訂の時間的余裕があり，しかも改訂後の状態を比較的長期にわたり持続の可能性が考えられる場合（例えば，キグチおよびエビ漁の春キグチから夏および秋キグチ漁への転換時および秋エビから冬，春エビへの転換時等）には，奥袖上部の三角網部を取り除き，或るいは補充することで網口の高い改良型から網口の低い在来の網型へ，或るいはその逆と，必要に応じて1種の網具で2様の網具として使用する。この為には5角型の奥袖部は一枚続きの網地で作製せず，あらかじめ上部と下部は別々な網地を縫い合わせ三角部分を取りつけ，取り離し，自在にしておけば実際の操作に当って極めて便利である。

（2）次に網具改訂が急を要し，或るいは改訂そのものの時間的余裕はあっても，前の如く比較的長期間一定状態を持続せず，短期間内にしばしば繰り返し改訂を必要とする場合（例えば，キグチおよびタチ等の潮汐変化に応ずる場合，或いはタチ，ハモおよびシログチ等の昼夜の変化に応ずる場合）には前述の如くいちいち三角網部の取り離し，或いは取り付けを行なっていたのでは時間的にも間に合わないときもあり，また繰り返しの改訂は極めて繁雑なことである。従ってこの場合には，網具はそのままに，天井前縁両脇端および両補助力綱に止め金をあらかじめそなえておき，必要に応じてそれらを止め合わせることで，一時的な方法であるが，前述の如く両様の網具としての効果を発揮さす。この場合余分になった三角網部の網成りへの影響が一応問題と考えられるが，その部の外観を多少悪くする程度で，全体的な網成りへの悪影響はほとんど認められない。なお，上述の止め金の代りにその間をロープで結び，そのロープの長さを適当に短かくすることで，三角網部の高さを絞れば，網口も任意の高さに調整することができ，対象魚種の状況によっては極めて便利である。

（3）また，魚群の垂直的な移動が大きく，しかもその移動変化が短期間内に種々変る場合（即ちエビ漁の春エビの昼夜の変化，或るいは越冬群から北上群への転換時等の場合）には底曳漁法だけでなく，中層曳漁法への転換が要望される。この場合には前に述べた如く，本網具の特性を活用し，グランドロープに巻きつけられている重錘用のチェーンを取り除くと網部は普通浮上する性質がある。従って一般の中層曳網の操法の如くロープの長さおよび曳網速度を適当に調整することにより，容易に中層曳網具としての性能を発揮し，必要に応じ直ちに元の底曳網操法にひきもどすことも可能である。この場合，中層曳網として使用する場合は荒手部は必要でなく，却って，その成果を阻害するものであるので，これも取り付け，取り離しが自在にできるよう処置しておけば，極めて操作上便利である。

以上の網具の改訂および調整のほかに，これらの結果を更に効果的にするには，両船間隔，曳網速度，或るいは浮子，沈子類等の操作上の要因をも総合的に考慮し，それを助長せしめるように，しむけなければならないことはいうまでもないことである。

要　　約

在来の網具を如何に改良すれば，より効果的に網口を高め，その漁獲の向上が期せられるかについて種々その方法を検討した。

その手初めとして，特殊拡口装置等取り扱いに不便なものを用いる方法は，実用的価値が極めて少ないことを考慮し，ここでは只一本の補助力綱を基とした網具の設計上の適当な処理法だけで，極めて簡単に網口の高さが自動的に相当高まるよう考案された $S-I$ 型網が，網成りおよび抵抗等力学的にみてその性能はどうであるか模型実験により観測し，その結果を在来の網具の前報の結果と比較検討した。

ついで，この網は実際の操業において，在来の網具に比べて対生物的にどれほどの効果があったか，キグチ，或るいはエビ等各重要魚を対象に，数年に亘り実際操業された結果についても比較検討した。

それらの概要を述べると次のとおりである。

1. 両手木間隔が比較的狭い範囲ではその広狭により網口の横ならびに高さの方向の拡がりとも互いに逆ではあるが，相当増減し，或る一定の間隔（20～30 m）以上になると，その広狭は網口附近の網成りには，ほとんど影響を及ぼさないことは両網具ともほぼ共通である。しかし，その両手木間隔を拡げるにつれて拡がり，或るいは低下する網口附近の横，或るいは高さの方向への変化の割合は，本網具のそれが共に在来の網具のそれより小さく，且つ本網具の高さは常に在来の網具のそれより高いが，横へは逆に狭く拡がっている。従って両網具のこれらの差は間隔が大きくなるにつれ増大する傾向がある。

抵抗は手木間隔の拡大と共に急激に増加し，その増加の割合はやはり手木間隔が 30 m 前後を境に，それより広い範囲で狭い範囲のものより大きいことは両網具共にいえるが，やはり抵抗値はこの網のものが在来の結果より大きい。しかして両者の差は間隔が大きく開かれるにつれ増加する。

2. 網口附近の横方向への拡がりは，在来の網具の場合と同様速度にかかわりなくほぼ定状をなしているが，速度増加に伴う高さの低下の割合は極めてわずかで，在来のものの如き急激な低下はみられない。しかもその網口の拡がり方は在来の網具に較べて常に高さは高く，横方向へは逆に狭く観測された（即ち 2.5 ノット時の本網具の網口における高さおよび水平的な拡がりは，在来の網具のそれらよりそれぞれ 2 倍および 1.6 割前後高く，また巾狭くなっている）。

なお，速度変化による袖網および嚢口附近の網成り変化はほとんど認められないが，これらの網立ちもやはり在来の網具の場合より相当高い。

抵抗については，速度が 1～4 ノットの範囲内では，抵抗が速度の自乗にほぼ比例して増加することは在来の網具の結果と同様であるが，抵抗値は本網具が在来のものより約 1.4 倍大きく観測された。

3. 浮子の効果は，この網には在来の網具の場合よりは多少認められるが，網口の高さを高めるためにはあまり役立たない。この網では，この浮子に関することよりも，むしろ，天井網等上網部に働く揚力で全体的に網具が浮上することの問題が重要で，その扱い方いかんによっては中層曳操法等に極めて有利に活用できるが，底曳網としては従来使用されていたグランドロープ等の重さを 2 倍程度大きくし，網の浮上を防止せねばならない。

4. *S-I* 型網具のキグチ，エビ等各重要魚種への効果については，それらが漁期，漁場，昼夜，潮汐およびその他の要因により，それぞれ異なった群構造をなすので一概にいえないが，

a）キグチ漁においては，3 月下旬から 4 月中旬にかけて漁獲される春キグチおよび，7 月から 8 月下旬の夏キグチ等は魚群構造も立体的で，この場合は網口の高い改良型網具による操業が効果的であり，漁獲成績も在来の網具に較べ相当高い。しかし 9 月から 11 月にかけて操業される秋キグチでは，魚群は海底附近に平面的な分布をなし，逆にこの場合は在来の網口の低い網具による漁獲成績が良好である。

b）コウライエビ漁においては，45°—30′ N 線以北漁場の 12 月上旬から同下旬（時により 1 月上旬）にかけての南下移動群および 3 月下旬から 4 月上旬の北上移動後期のエビ群は，群構造が海底に接した極めて水平的なものであるので，全く効果はなく，むしろこの場合は在来の網具で操業した方が漁獲成績は良好である。しかし，45°—30′ N 線以南の漁場の 1 月上旬，若しくは中旬から 3 月上旬までの越冬期および北上前期の魚群では，群全体が海底より浮上し，しかもその上部は非常に上層にまで及ぶ極めて立体的な群構造がみられ，全く本改良型の独断場といわれ，在来の網具では全々漁獲されないが，本網具による漁獲の成績は極めて良好である。なお，越冬期，或るいは北上前期の夜間における魚群に対しては，この網具の特性を活用した中層曳的操法をなすことにより，相当の成果が得られたようである。

c）その他の魚種では，タチウオおよびハモ漁には本改良型網の方が漁獲成果は大きいが，シログチ，カレイおよびタイ類の如く，常に海底附近に低く水平的な分布をなしている魚群に対しては，逆に，やはり在

来の網具の成果が大である。

終りに本実験について，或るいは本網具の実用化等について終始ご協力を賜わった日本漁網船具(株)，日米水産(株) の関係各位に深甚の謝意を表する。

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PLATES

PLATE I

The top- and side- photographs of the net at various distance between two spreaders attaching each frontal end of the wings under 2.5 miles/hour towing speed.

PLATE II

The top- and side- photographs of the net at various towing velocity under 33.2 m in the distance between two spreaders attaching each frontal end of the wings.

油なめし法の検討 その六※

松　沢　定五郎

Considerations on Oil Tanning (6th) ※

By

Jōgorō MATSUZAWA

In this paper, maturity of the oil agents is followed. In the previous papers, oil tanning progresses in the conditions: temperature 30～50°C, relative moisture 85%. Therefore the maturity of the tanning oils will occur in these conditions, if it occur.

As oil agents Japanese sardine oil, its mixed fatty acids in petroleum or in methanol were used for these experiments, and they were processed by above conditions.

The results of these experiments are able to be noted as follows.

1) About sardine oil, maturity for tanning was likely thought to reduce the tanning days more or less, or attain higher Ts of the oiled skins than ordinary oil agents.

2) No maturity of tanning agents, which was similarly developed by the ordinary oil agents and matured ones in day required to tan and Ts attained in the same tanning days, took place in its mixed fatty acids.

油剤の熟成について

油なめしにおいて油剤と皮と接触させると吸着が起る。そして両者の結合は吸着後直ちに進行するとも，また直ちには結合せず油剤が或る程度変性して後初めて結合を開始するとも考え得る。

仮りに油剤が或る程度の変性即ち熟成後結合するものであれば，油なめし法は当初から油剤と皮とを接触させる常法によらずに，油剤を熟成させて然る後接触させても目的を達し得る筈である。

既往の実験において油なめしの進行するのは大体温度30～50°C，関係湿度85%の環境下である。従って油剤の熟成という現象がありとするならばこの条件下において起るものと考えられる。

この項の実験においては上記の条件下に処理して油剤が油なめしを進行させるか否かを検討することを主題とした。

(1) 方　　法

各種の油剤を所定の温度および湿度の湿干箱中に静置してその変性を行なった。そしてその静置時間即ち熟成時間を変えたその油剤を以って試料皮の油なめしを行ない，そのなめしの進行状況をTsの測定によって観察することにした。

試料皮は全実験を通じて次の処理を施したさめ皮である。即ち塩干皮を払鱗後流水中に一夜浴漬して脱塩

※ 水産講習所研究業績　第346号，1961年10月25日 受理.
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し，次いで軽油中に漬もみを行ないながら乾燥し柔軟な乾皮とした。

(2) 実 験

各実験において測定したTsの移動は次表のとおり。

Table 1. Tanning ability of matured sardine oil.

No. \ Date	Ts of the samples																	Maturing days	Container
	June 3	〃 10	〃 17	〃 24	July 1	〃 8	〃 15	〃 22	〃 29	Aug. 12	〃 19	〃 27	Sept. 3	〃 10	〃 17	〃 22	〃 30		
1	47.5	43.5	39.5	40.5	41.5	43.5	47.5	47.5	45.5	51.5	52.5	53.5	54.5	55.5	56.5	56.5	57.5	0	
2		47.5	40.5	42.5	44.5	45.5	49.5	49.5	50.5	53.5	54.5	54.5	56.5	57.5	56.5	58.5	58.5	7	
3			47.5	45.5	46.5	47.5	50.5	48.5	50.5	52.5	53.5	55.5	56.5	56.5	58.5	58.5	59.5	14	
4				49.5	47.5	47.5	49.5	50.5	49.5	51.5	53.5	53.5	53.5	54.5	56.5	59.5	58.5	21	Beaker
5					48.5	49.5	50.5	49.5	49.5	52.5	52.5	54.5	54.5	54.5	55.5	58.5	57.5	28	
6						50.5	51.5	48.5	48.5	48.5	49.5	50.5	51.5	52.5	53.5	55.5	56.5	35	
7							48.5	50.5	47.5	52.5	55.5	55.5	56.5	58.5	58.5	60.5	61.5	42	
8								48.5	48.5	49.5	50.5	50.5	50.5	51.5	54.5	56.5	57.5	49	
9									49.5	47.5	45.5	46.5	49.5	51.5	53.5	54.5	56.5	56	
10							47.5	47.5	49.5	57.5	59.5	60.5	61.5	61.5	61.5	62.5	60.5	42	
11								48.5	47.5	50.5	51.5	51.5	…	58.5	59.5	60.5	59.5	49	Petri dish
12									48.5	50.5	51.5	54.5	59.5	59.5	61.5	61.5	62.5	56	

Skin…Dry, soft shark skins
Tanning Method…Dip tanning
Moisture…85 % (about)
Temp.…30°C, to Aug. 5
35°C, to Sept. 3
40°C, other days

Table 2. Tanning ability of matured sardine oil.

No. \ Date	Ts of the samples														Sept. 2					Maturing days	Container
	July 12	〃 15	〃 19	〃 22	〃 26	〃 29	Aug. 2	〃 8	〃 12	〃 16	〃 19	〃 22	〃 26	〃 30		〃 10	〃 16	〃 22	〃 30		
13	49.5	43.5	45.5	48.5	50.5	51.5	53.5	55.5	56.5	57.5	57.5	57.5	57.5	59.5		59.5	60.5	61.5	61.5	0	
14		47.5	46.5	48.5	51.5	50.5	52.5	53.5	55.5	56.5	56.5	55.5	56.5	57.5		58.5	59.5	59.5	59.5	3	
15			48.5	46.5	46.5	46.5	47.5	49.5	50.5	53.5	51.5	51.5	52.5	54.5		55.5	57.5	58.5	59.5	7	
16				48.5	45.5	46.5	47.5	49.5	50.5	50.5	52.5	54.5	54.5	56.5		57.5	58.5	59.5	60.5	10	Beaker
17					48.5	47.5	46.5	46.5	48.5	49.5	49.5	50.5	50.5	52.5		53.5	54.5	57.5	58.5	14	
18						48.5	44.5	45.5	49.5	50.5	50.5	50.5	51.5	54.5		55.5	56.5	58.5	60.5	17	
19							47.5	45.5	46.5	48.5	47.5	49.5	51.5	52.5		54.5	55.5	58.5	59.5	21	
20								49.5	46.5	45.5	45.5	48.5	49.5	51.5		54.5	56.5	57.5	60.5	27	
21									48.5	44.5	…	45.5	46.5	47.5		49.5	52.5	55.5	57.5	31	
22										48.5	…	48.5	46.5	49.5		52.5	55.5	57.5	59.5	35	
23											50.5	50.5	50.5	55.5		57.5	59.5	61.5	61.5	38	Petri dish
24													47.5	…		54.5	58.5	58.5	61.5	41	

Skin…Dry, soft shark skins
Tannig Method…Dip tanning
Moisture…85 % (about)
Temp.…30°C for July 12～Aug. 3
35°C for Aug. 4～Sept. 3
40°C for other days

Table 3. Tanning ability of matured sardine oil and mixed fatty acids in petroleum.

No. \ Date	Ts of the samples																				
	Oct. 3	〃 5	〃 7	〃 10	〃 12	〃 14	〃 17	〃 19	〃 21	〃 24	〃 26	〃 28	〃 31	Nov. 2	〃 4	〃 7	〃 9	〃 11	〃 14	〃 16
25	48.5	46.5	50.5	53.5	56.5	59.5	51.5	60.5	62.5	63.5	62.5	63.5	63.5	62.5	62.5	67.5	68.5	68.5		
26		50.5	48.5	50.5	53.5	55.5	56.5	55.5	56.5	55.5	55.5	54.5	57.5	58.5	58.5	58.5	…	58.5	…	58.5
27			48.5	49.5	50.5	51.5	54.5	53.5	55.5	55.5	57.5	56.5	55.5	56.5	57.5	57.5	57.5	60.5	59.5	59.5
28				48.5	50.5	50.5	53.5	53.5	53.5	54.5	54.5	53.5	54.5	54.5	53.5	52.5	53.5	55.5	56.5	57.5
29					49.5	47.5	50.5	50.5	53.5	54.5	54.5	56.5	57.5	57.5	57.5	58.5	59.5	…	…	52.5
30						49.5	52.5	52.5	53.5	54.5	55.5	53.5	55.5	56.5	57.5	59.5	59.5	56.5	57.5	57.5
31							49.5	50.5	48.5	49.5	51.5	50.5	53.5	53.5	50.5	50.5	49.5	50.5	50.5	52.5
32								46.5	47.5	50.5	…	46.5	50.5	51.5	51.5	48.5	50.5	49.5	53.5	54.5
33														46.5	48.5	56.5	59.5	61.5	62.5	61.5
34	49.5	46.5	44.5	46.5	48.5	50.5	52.5	55.5	57.5	61.5	63.5	63.5	65.5	66.5	64.5	64.5	69.5	71.5		
35					48.5	45.5	47.5	46.5	47.5	50.5	51.5	53.5	59.5	58.5	58.5	59.5	60.5	61.5	60.5	60.5
36														46.5	48.5	49.5	51.5	54.5	56.5	58.5

No. \ Date	Ts of the samples								Maturing days
	Nov. 18	〃 21	〃 23	〃 25	〃 28	〃 30	Dec. 2	〃 5	
25									0
26									2
27									4
28	55.5								7
29	51.5	50.5							9
30	58.5	57.5							11
31	51.5	53.5	55.5	59.5					14
32	54.5	52.5	54.5	60.5	57.5	54.5			16
33	63.5	64.5	63.5	62.5	61.5	62.5	61.5	…	29
34									0
35	61.5								9
36	60.5	64.5	62.5	63.5	63.5	64.5	64.5	65.5	29

Skin…Dry, soft shark skins
Oil agents…Fatty acids in petroleum for No. 1～No. 9
Sardine oil for No. 10～12
Temp.…30°C for the 1st and 2nd week
40°C for the 3rd week
50°C for the other weeks
Moisture…85 %

Table 4. Tanning ability of matured sardine oil and its mixed fatty acids in methanol.

No.	Matured days	Ts of the samples											
		Original	Mar. 3	〃 6	〃 8	〃 10	〃 13	〃 15	〃 17	〃 20	〃 22	〃 24	〃 27
	57	51.5	48.5	51.5	54.5	57.5	64.5	59.5	62.5	62.5	62.5	69.5	69.5
	43	51.5	49.5	51.5	54.5	56.5	59.5	60.5	67.5	63.5	60.5	69.5	64.5
	29	51.5	49.5	51.5	54.5	57.5	63.5	61.5	63.5	67.5	68.5	68.5	68.5
	15	51.5	48.5	50.5	53.5	54.5	57.5	55.5	59.5	57.5	65.5	61.5	61.5
	0	51.5	44.5	52.5	56.5	58.5	59.5	60.5	60.5	61.5	62.5	60.5	59.5
	8	51.5	48.5	55.5	58.5	60.5	61.5	59.5	61.5	62.5	59.5	61.5	65.5
	6	51.5	47.5	53.5	60.5	60.5	60.5	60.5	60.5	63.5	63.5	64.5	59.5
	4	51.5	47.5	55.5	59.5	61.5	62.5	64.5	65.5	65.5	63.5	66.5	61.5
	2	51.5	47.5	53.5	56.5	60.5	59.5	59.5	61.5	62.5	61.5	61.5	66.5
	80	51.5	54.5	61.5	64.5	65.5	66.5	65.5	65.5	66.5	66.5	66.5	61.5

Oil Agents…Mixed fatty acids in methanol for No. 6～10
Sardine oil for No. 1～No. 5
Temp.…40°C
Moisture…85 % (about)

(3) 考　　察

第1表より各試料の到達した最高 Ts および到達するに要した日数を表示すると次のようになる。

第5表をみる。ビーカー容の試料についてはその油剤と皮との初めの接触日数7週間内において試料の到達した最高 Ts は49.5～58.5°C の範囲でありNo. 6を除くと油剤の熟成の数の多いものがその最高 Tsは高い傾向にある。しかし各試料の受けた処理温度は同一でない。故にこの傾向は更に検討の必要があろう。

シャーレー容の試料につき同様に見ると，その最高Tsの範囲は 60.5～62.5°C の範囲でその数値は近接し

Table 5. (from Table 1).

No.	Maturing days	Highest Ts for 7 weeks	Highest Ts for all weeks	Days required	Reffe-rence
1	0	49.5	57.5	112	in beaker
2	7	53.5	58.5	98	
3	14	53.5	59.5	98	
4	21	53.5	59.5	84	
5	28	54.5	58.5	77	
6	35	52.5	56.5	77	
7	42	58.5	61.5	70	
8	49	56.5	57.5	63	
9	56	56.5	55.5	56	
10	42	61.5	62.5	63	in Petri dish
11	49	60.5	60.5	56	
12	56	62.5	62.5	56	

Table 6. (from Table 2).

No.	Maturing days	Highest Ts for 1 month	Highest Ts for all days	Days required	Reffe-rence
13	0	57.5	61.5	72	in beaker
14	3	56.5	59.5	63	
15	7	53.5	59.5	72	
16	10	54.5	60.5	70	
17	14	52.5	58.5	66	
18	17	54.5	60.5	63	
19	21	54.5	59.5	59	
20	27	56.5	60.5	53	
21	31	55.5	57.5	49	
22	35	59.5	59.5	45	in Petri dish
23	38	59.5	61.5	34	
24	45	61.5	61.5	34	

ている。

更に測定記録全体を見ると，いずれにおいても油剤の熟成日数の長いものが最高Tsに到達する日数の少ない傾向にある。

第6表を見る。レーカー容器料において，油剤と皮との接触日数4カ月内の各試料の到達した最高Tsはその52.5～59.5°Cの範囲ではその序列と油剤熟成日数との間には相関関係が見られない。

また測定記録全体を通してみると各試料の最高Tsに到達した日数の比較においては油剤の熟成日数の多いものは到達所要日数が少なくなる傾向にある。

第7表により油剤と皮と5週間の接触結果を見れば混合脂肪酸群においては最高Tsの範囲は52.5～62.5°Cの範囲でその序列と油剤と熟成日数との間には相関関係が認められない。

いわし油群においては最高Tsの範囲は61.5～66.5°Cの範囲であるが，その相関関係は明らかにし難い。

上記の3実験は共に油剤の熟成開始時日を同一にしたのであるが，その処理温度は経日的に漸次高めた結果各試料の処理温度は同一でない結果を来たした。第4の実験は油剤個々の熟成開始時日を異にし，油剤と皮との接触は同一時日より始めた。それで処理日時および温度等は全く同一条件になった。この成果は第8表に示される。

Table 7. (from Table 3).

No.	Maturing days	Highest Ts for 5 weeks	Highest Ts for all weeks	Days required	Oil agents
25	0	63.5	68.5	36	Mixed fatty acids in petroleum
26	2	58.5	58.5	27	
27	4	57.5	60.5	34	
28	7	53.5	57.5	36	
29	9	59.5	59.5	27	
30	11	59.5	59.5	23	
31	14	52.5	59.5	20	
32	16	54.5	60.5	39	
33	26	62.5	64.5	42	
34	0	66.5	71.5	38	Sardine oil
35	9	61.5	61.5	36	
39	29	64.5	64.5	28	

Table 8. (from Table 4).

No.	Maturing days	Highest Ts	Days required	Oil agents
37	0	62.5	19	Sardine oil
38	14	65.5	19	
39	28	68.5	19	
40	42	69.5	21	
41	56	69.5	19	
42	0	66.5	21	Mixed fatty acids in methanol
43	2	66.5	23	
44	4	66.5	21	
45	6	64.5	21	
46	8	65.5	23	

第8表によるといわし油群においては各試料の最高Tsの範囲は62.5～69.5°Cの範囲である。油剤の熟成日数0～56日間の比較においては，そのTsの序列は熟成日数に大体相応していることが示されている。前記各実験においてこの関連が示されなかった理由は油剤の熟成の影響が処理温度等のそれに優先し得なかったことにあるものと考えられる。混合脂肪酸メタノール溶液群においては最高Tsの範囲は64.5～66.5°Cの範囲でその差は僅少である。

(4) 総　　括

以上の考察を総合すると油剤がいわし油の場合にはその熟成日数と最高Tsとの関係は次のようになる。或る程度熟成日数を多くするとその最高Tsに到達する日数を少なくするか，或るいは同一接触期間内に到

達する最高 Ts を高めにする。然るに混合脂肪酸の場合においては両者の間に上記のような関連は見出し得ない。

従って，いわし油においては熟成と称し得る現象は認め得る。しかし記録の示すとおり実用的に効果のある程度ではない。混合脂肪酸においてはその現象は認め難い。即ち皮質と油剤との結合は接触時より開始するものと考えられる。

油なめし法の検討 その七※

松　沢　定　五　郎

Considerations on Oil Tanning (7th) ※

By

Jōgorō MATSUZAWA

In this report some solvents for tanning oils were experimented to attain high Ts of oiled shark skins.

Japanese sardine oil, its mixed fatty acids and its methyl- and ethylesters were used as tanning oils. As solvents, light petroleum, acetone, benzene, methanol, ethanol, and ethylene glycol were compared for this purpose.

These experiments display the undernoted results.

1) Methanol and ethanol are superior to other solvents for the purpose.

2) Methanol and ethanol are effective when they are applied in the former half of tanning, but not in the latter half.

3) And their effection is observed in the 1st addition and not in 2nd and after additions.

4) In case of washing the oiled skins with methanol the 1st, 2nd and after washing are all effective in attaining high Ts of the oiled skins.

5) Appling of the alcohols to tanning oil makes the tanning speed up, but the highest Ts (ultimately attained) of the oiled skins is almost the same as the ordinary oils only.

油剤の溶媒について

魚油，その混合脂肪酸またはそのメチルエステル等の油剤は温度変化によりその物理的性状を異にし，なめし進行中変性して皮膜或るいは沈澱を形成する。

油剤の物理的性状はその滲透性等に関連し，また皮膜或るいは沈澱はそのなめし能力に影響のあることが予想される。

従って油剤を適当溶媒で稀釈してその物理的性状を改善し，または皮膜或るいは沈澱の形成を有効に遅滞せしめることが可能となれば油なめしは更に円滑にまたは強力に進行することが期待される。この企図によ

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り若干の溶媒の性能を検討した。

実験 1　各種溶媒の比較

方法　油剤としては，いわし油の混合脂肪酸とそのメチールおよびエチールエステルの3種を用い，溶媒としては軽油，ベンゼン，エタノール，メタノールおよびアセトーンの5種を比較した。

原皮は軟化せしめた鮫干皮を使い，なめし法は湿熱中の漬なめし法を採用した。

成果　なめし進行中の試料の移動は第1表のとおり。

Table 1. Solvents for mixed fatty acid and esters.

No.	Oil agents	Solvents	Ts (°C) of the oiled skins													
			Nov. 28	〃 30	Dec. 2	〃 5	〃 7	〃 9	〃 12	〃 14	〃 16	〃 19	〃 21	〃 23	〃 26	Jan. 4	〃 6
1	Fatty acids	Peteroleum	46.5	42.5	45.5	49.5	51.5	54.5	59.5	60.5	61.5	62.5	62.5	63.5	64.5	64.5	63.5
2	Fatty acids	C_6H_6	45.5	41.5	48.5	50.5	52.5	56.5	57.5	59.5	60.5	62.5	61.5	62.5	62.5	64.5	62.5
3	Fatty acids	C_2H_5OH	45.5	49.5	57.5	60.5	61.5	64.5	62.5	62.5	62.5	63.5	…	64.5	62.5	…	62.5
4	Fatty acids	CH_3OH	45.5	49.5	54.5	59.5	62.5	65.5	66.5	67.5	67.5	68.5	66.5	68.5	68.5	67.5	…
5	Fatty acids	CH_3COCH_3	46.5	43.5	47.5	52.5	54.5	58.5	59.5	59.5	61.5	61.5	63.5	62.5	62.5	64.5	62.5
6	Ethyl esters	Peteroleum	45.5	47.5	49.5	53.5	58.5	62.5	62.5	61.5	60.5	63.5	63.5	63.5	62.5	63.5	62.5
7	Ethyl esters	C_2H_5OH	46.5	47.5	53.5	54.5	57.5	60.5	61.5	61.5	62.5	61.5	60.5	60.5	60.5	64.5	66.5
8	Ethyl esters	CH_3OH	47.5	47.5	52.5	54.5	58.5	61.5	62.5	63.5	62.5	62.5	59.5	64.5	62.5	64.5	63.5
9	Methyl esters	Peteroleum	45.5	42.5	45.5	49.5	55.5	58.5	56.5	58.5	56.5	60.5	61.5	63.5	64.5	59.5	59.5
10	Methyl esters	CH_3OH	45.5	45.5	53.5	54.5	58.5	60.5	64.5	63.5	64.5	67.5	66.5	66.5	67.5	70.5	67.5

Mixed fatty acids…from Japanese sardine oil; by cold soaponification process.
Esters…Esterified under refluxation for 1.5 hrs.
Skins…Salted, dry shark skin, desalted in running water, softend in petroleum, and dryed.
Tanning…by dipping method, under 28～40°C and relative moisture 85 %.

考察　脂肪酸群について見ると

(1)　溶剤別 Ts の初期移動が複雑に現われている。この点のみを第1表より抜き書きすると第2表となる。

Table 2. The highest Ts for solvents (from Table 1).

No.	Solvents	Ts		
		Nov. 28 Original	Nov. 30	Difference
1	Petroleum	46.5	42.5	−4
2	Benzene	45.5	41.5	−4
5	Acetone	46.5	43.5	−3
4	Methanol	45.5	49.5	+4
3	Ethanol	45.5	49.5	+4

軽油ベンゼンおよびアセトーンを溶媒とする場合には Ts の初期低下が見られ，メタノールおよびエタノールの場合にはそれがないことが注目される。

既報の実験において脂肪酸を単用し或るいは魚油に配合して併用した場合にこの初期低下が現われている。

(2)　到達した最高Tsを列記すると第3表となる。

Table 3. The highest Ts in order (from Table 1) (solvents).

No.	Solvent	Highest Ts	Days lapsed
4	Methanol	68.5	21
3	Ethanol	64.5	11
1	Petroleum	64.5	28
2	Benzene	64.5	27
5	Acetone	64.5	37

この表からメタノールおよびエタノールはその最高Tsが高いか或るいはそれに達する日数が他の溶媒のものに比べて少ないことが看取される。

エステル群について見ると

(3) 初期Tsの低下はNo. 9に−30°Cが記録され，他には現われていない。既往の実験においてはエステルを油剤とした場合にはこの初期低下はなかったもので本例は異例に属する。

(4) 最高Tsを比較すると第4表のようになる。

Table 4. The highest Ts in order (from Table 1) (oil agents and solvents).

No.	Oil agent	Solvent	Highest Ts	Days required
10	Methyl ester	Methanol	70.5	37
7	Ethyl ester	Ethanol	66.5	39
9	Methyl ester	Petroleum	64.5	28
8	Ethyl ester	Methanol	64.5	25
6	Ethyl ester	Petroleum	63.5	21

この表により，メタノールおよびエタノールのものは軽油のそれに比べその最高Tsは同じか或るいは高く現われている

(5) 上記の結果からメタノールおよびエタノールは油剤の溶媒としては他より勝れたものといい得る。

実験 2 メタノールとエタノールの効果

Table 5. Comparative effect of methanol and ethanol solvents to various oil agents, tanning conditions are same to Table 1.

No.	Tanning oil	Alcohol	Ts (°C) of the oiled skins														
			May 8	〃 10	〃 12	〃 15	〃 17	〃 19	〃 22	〃 24	〃 26	〃 29	〃 31	June 2	〃 5	〃 7	〃 9
11	Sardine oil	···	48.5	45.5	47.5	48.5	52.5	52.5	···	54.5	56.5	58.5	···	61.5	61.5	···	62.5
12	Sardine oil	C_2H_5OH	48.5	49.5	50.5	53.5	55.5	58.5	61.5	62.5	65.5	65.5	···	67.5	68.5	···	68.5
13	Sardine oil	CH_3OH	48.5	49.5	51.5	54.5	55.5	57.5	61.5	63.5	64.5	63.5	···	66.5	66.5	···	65.5
14	Mixed fatty acids	···	49.5	48.5	49.5	53.5	56.5	56.5	57.5	58.5	57.5	58.5	···	61.5	62.5	···	65.5
15	Mixed fatty acids	C_2H_5OH	49.5	52.5	60.5	62.5	63.5	65.5	65.5	65.5	66.5	66.5	···	69.5	75.5	···	70.5
16	Mixed fatty acids	CH_3OH	48.5	50.5	57.5	62.5	63.5	65.5	65.5	66.5	65.5	65.5	···	66.5	70.5	···	67.5
17	Ethyl ester	C_2H_5OH	49.5	54.5	58.5	62.5	···	61.5	62.5	62.5	62.5	61.5	···	64.5	66.5	···	70.5
18	Ethyl ester	CH_3OH	49.5	57.5	60.5	63.5	62.5	63.5	64.5	65.5	64.5	65.5	···	65.5	66.5	···	63.5
19	Methyl ester	C_2H_5OH	48.5	54.5	57.5	59.5	60.5	59.5	64.5	63.5	62.5	62.5	···	66.5	62.5	···	68.5
20	Methyl ester	CH_3OH	48.5	50.5	55.5	56.5	62.5	65.5	65.5	65.5	66.5	65.5	···	66.5	66.5	···	70.5
21	Methyl ester	$(CH_2OH)_2$	49.5	50.5	49.5	53.5	57.5	56.5	55.5	54.5	55.5	55.5	···	58.5	60.5	···	62.5

方法　いわし油，その混合脂肪酸およびエステル等の油剤に対しアルコールを併用してその効果を求めた。原皮，なめし法等は同前。

成果　第5表のとおり

考察　第5表より各試料の最高 Ts を列記すると次表となる。

Table 6. The highest Ts for oil agents and solvents (from Table 5).

No.	Oil agents	Solvent	Highest Ts	Days required
15	Fatty acids	Ethanol	75.5	28
16	Fatty acids	Methanol	70.5	28
17	Ethyl ester	Ethanol	70.5	32
20	Methyl ester	Methanol	70.5	32
12	Sardine oil	Ethanol	68.5	28
19	Methyl ester	Ethanol	68.5	32
13	Sardine oil	Methanol	66.5	35
18	Ethyl ester	···	66.5	28
14	Fatty acids	···	65.5	32
11	Sardine oil	···	62.5	32
21	Methyl ester	Ethylene glycol	62.5	32

この表によると，メタノールおよびエタノールを溶媒として使用した試料のTs は75.5～66.5°C を示し，その溶媒を併用しない，即ち対称区は66.5～62.5°C を示している。

メタノールとエタノールの比較はその成績が錯雑していて明確な判定は困難である。ただ2価アルコールのエチレングリコールはTs上昇には無力であることは明瞭である。

実験　3　　なめし温度

方法　油剤としては混合脂肪酸およびそのエステルまた溶媒としてはエタノールおよびメタノールを用いた。このなめしは早く行なわれるので処理温度を40°Cより始め，連日2～3°C宛上昇させめ55°Cに至らせた。

成果　第7表のとおり

Table 7. Effect of temperature on tanning.

No.	Tanning agent		Ts (°C) of the oiled skins							
	Oil	Alcohol	Jan. 10	〃 11	〃 12	〃 13 14	〃 15	〃 16	〃 17	18
22	Mixed fatty acids	Methanol	49.5	···	56.5	···	···	63.5		Culred
23	Mixed fatty acids	Ethanol	49.5	···	53.5	···	···	53.5		Culred
24	Methyl ester	Methanol	50.5	···	57.5	···	···	58.5		Culred
25	Methyl ester	Ethanol	48.5	···	58.5	···	···	59.5		57.5
26	Ethyl ester	Methanol	49.5	···	56.5	···	···	55.5		55.5
27	Ethyl ester	Ethanol	49.5	···	54.5	···	···	54.5		54.5
Temperature, in the tanning box			40°C	42	45	47	50	55	55	55

考察　No. 22試料は55°Cで変調を来した。他の47～50°CでTs上昇速度が鈍化した。

この現象から見ると，処理温度は最初を除くと10°C程度試料皮のTsより低くすることが安全である。

実験 4 アルコール添加回数の効果

油剤にアルコールを併用すると油皮の Ts 上昇速度を早める結果を得た。そしてこのアルコールは処理温

Table 8. Effect of methanol addition times on oil tanning.
Temp. of tanning Box…30~38°C

No.	Tanning agents		Ts of the oiled skins (°C)										
	Oil	CH_3OH	Mar. 27	〃 29	〃	31	Apr. 3	〃 5	〃	7	〃 10	〃 12	〃 14
36	Mixed fatty acids	…	48.5	50.5	60.5	…	65.5	67.5	67.5	…	69.5	…	…
37	Mixed fatty acids	CH_3OH	48.5	61.5	65.5	…	66.5	65.5	67.5	…	66.5		
38	Mixed fatty acids	CH_3OH	48.5	58.5	63.5	Add. 2 nd	66.5	67.5	67.5	…	65.5		
39	Mixed fatty acids	CH_3OH	48.5	60.5	61.5	Add. 2 nd	64.5	65.5	65.5	Add. 3 rd	64.5		
40	Mixed fatty acids	CH_3OH	48.5	60,5	63.5	Add. 2 nd	65.5	65.5	65.5	Add. 3 rd	66.5		
41	Mixed fatty acids	CH_3OH	48.5	60.5	63.5	Add. 2 nd	65.5	65.5	66.5	Add. 3 rd	66.5		
42	Mixed fatty acids	CH_3OH	48.5	61.5	63.5	Add. 2 nd	65.5	65.5	65.5	Add. 3 rd	66.5		
43	Sardine oil	CH_3OH	48.5	63.5	66.5	Add. 2 nd	66.5	67.5	69.5	Add. 3 rd	69.5		
44	Sardine oil	…	48.5	51.5	58.5	…	61.5	63.5	65.5	…	66.5		
45	…	CH_3OH	48.5	54.5	…		…	…	…		…		

No.	Apr. 17		〃 19	〃 21	〃 24	〃 26	〃 28	May 1
36	71.5	…	70.5	…	…	69.5	…	68.5
37	67.5	…	67.5	…	…	68.5	…	68.5
38	67.5	…	67.5	…		68.5	…	68.5
39	67.5	…	65.5	…		67.5	…	68.5
40	68.5	Add. 4 th	66.5	…		70.5	…	66.5
41	67.5	Add. 4 th	67.5	Add. … 5 th		68.5	Add. … 6 th	66.5
42	69.5	Add. 4 th	66.5	Add. … 5 th		68.5	Add. … 6 th	66.5
43	72.5	Add. 4 th	71.5	Add. … 5 th		71.5	…	68.5
44	67.5	…	70.5	…		69.5	…	68.5
45	…	…	…			…		…

度下では1～4日間殆んど全部は揮散する。よってなめし期間中アルコールを補給すればどんな結果を得るかを検討してみた。

方法 大体の方法は前記実験と同じであるが，第9表のようにアルコールを0～6回補給した点が異なる。

成果 第9および10表のとおり。

Table 9. Effect of methanol addition times on oil tanning.
Temp. of tanning box…30°C±2°C

No.	Tanning agents		Ts of the oiled skins (°C)																	
	Oil	CH_3OH	Apr. 10	〃 12		〃 14		〃 17		〃 19		〃 21	〃 24	〃 26		〃 28	May 1	
28	Mixed fatty acids	…	48.5	48.5	…	50.5	…	51.5	…	57.5	…	63.5	…	65.5	…	…	66.5	…
29	Mixed fatty acids	CH_3OH	47.5	56.5	…	57.5	…	59.5	…	60.5	…	62.5	…	62.5	…	…	63.5	…
30	Mixed fatty acids	CH_3OH	48.5	54.5	Add. 2 nd	55.5	…	63.5	…	62.5	…	62.5	…	63.5	…	…	62.5	…
31	Mixed fatty acids	CH_3OH	48.5	56.5	Add. 2 nd	58.5	Add. 3 rd	62.5	…	63.5	…	63.5	…	65.5	…	…	65.5	…
32	Mixed fatty acids	CH_3OH	47.5	57.5	Add. 2 nd	58.5	Add. 3 rd	62.5	Add. 4 th	63.5	…	62.5	…	65.5	…	…	65.5	…
33	Mixed fatty acids	CH_3OH	48.5	56.5	Add. 2 nd	60.5	Add. 3 rd	57.5	Add. 4 th	62.5	…	64.5	…	67.5	Add. 5 th	…	66.5	Add. 6 th
34	Sardine oil	CH_3OH	48.5	53.5	Add. 2 nd	54.5	…	60.5	Add. 3 rd	61.5	…	63.5	…	67.5	Add. 4 th	…	68.5	Add. 5 th
35	Sardine oil	…	48.5	49.5	…	49.5	…	56.5	…	54.5	…	52.5	…	64.5	…	…	65.5	…

No.	May 3	〃 5	〃 8	〃 10	〃 12
28	…	…	67.5	…	69.5
29	…	…	64.5	…	66.5
30	…	…	63.5	…	68.5
31	…	…	67.5	…	67.5
32	…	…	67.5	…	68.5
33	…	…	68.5	…	69.5
34	…	…	70.5	…	71.5
35	…	…	68.5	…	69.5

考察 第1回のアルコール添加の効果は著明に現われている。即ち第9表においては無添加群の上昇は0～1°C，第10表においては2～3°Cであり，添加群のそれはそれぞれ5～10°C，10～15°Cとなっている。然るに第2回以後の添加効果は認められない。

また各試料の最高 Ts を見てもその序列とアルコール添加回数との間には関連がない。

なお，第9表のメタノール処理のみでTsが6°C上昇している。そしてこれに対する油剤にメタノールを添加した試料は10～15°Cの上昇があり大体の2倍に当っている。

この事実から考えると，メタノール効果は当初においては累加的とも思い得るが，最高 Ts を比較すると累加的とするよりは促進的である。

実験 5　アルコールの添加時期その他

メタノールは油脂の過酸化物の一部を溶解する性質がある。そして漬なめし中油剤は時日の経過に従って過酸化物の量を累増する、終には沈澱する。これの適当時期にメタノールを加えてその沈澱化を遅滞させた場合，そのなめしがどうなるか。またその反対に漬なめし中油皮に吸着された過酸化物をメタノールで洗い落す場合は，そのなめしがどうなるか。その2点を主題とした。

方法　油剤（脂肪酸）へのメタノール添加時期を当初第1，2，3および4週後とやるものと，試料を当初1回および毎週メタノール処理する。

その他は前実験法による。

成果　第10表のとおり。

Table 10. Effect of alcohol addition method.
Tanning temp.…40°C

No.	Tanning oil	Methanol addition	Skin	Ts of the oiled skins						
				June 14	〃 16	〃 19	〃 21	〃 23	〃 26	〃 28
46	Fatty acids	…	Air dried	48.5	47.5	53.5	55.5	55.5	59.5	62.5
47	Fatty acids	at beginning	Air dried	48.5	65.5	61.5	65.5	64.5	67.5	67.5
48	Fatty acids	after a week	Air dried	48.5	49.5	51.5	59.5	60.5	62.5	62.5
49	Fatty acids	after 2 weeks	Air dried	48.5	49.5	50.5	54.5	56.5	58.5	58.5
50	Fatty acids	after 3 weeks	Air dried	48.5	49.5	51.5	53.5	56.5	59.5	60.5
51	Fatty acids	after 4 weeks	Air dried	48.5	49.5	51.5	52.5	57.5	58.5	60.5
52	Fatty acids	…	Air dried, processed with methanol	48.5	54.5	51.5	52.5	56.5	58.5	61.5
53	Methyl ester	at beginning	Air dried	48.5	51.5	56.5	58.5	59.5	62.5	62.5
54	Methyl ester	…	Air dried, processed with methanol	48.5	52.5	55.5	54.5	56.5	58.5	57.5
55	Sardine oil	at beginning	Air driod	48.5	49.5	58.5	57.5	58.5	58.5	61.5
56	Fatty acids	…	Air dried, processed with methanol every week	48.5	49.5	51.5	56.5	59.5	59.5	63.5
57	Methyl ester	…	Air dried	48.5	45.5	50.5	51.5	51.5	53.5	54.5
58	Methyl ester	at beginning in room temp.	Air dried	48.5	49.5	54.5	54.5	55.5	55.5	58.5

No.	June 30	July 3	〃 5	〃 7	〃 10	〃 12	〃 14	〃 19
46	65.5	62.5	64.5	65.5	69.5		82.5	…
47	67.5	68.5	69.5	70.5	70.5		69.5	…
48	63.5	64.5	65.5	67.5	69.5		70.5	…
49	60.5	62.5	63.5	62.5	65.5		68.5	…
50	60.5	63.5	60.5	60.5	65.5		65.5	…
51	61.5	62.5	63.5	64.5	66.5		68.5	…
52	64.5	62.5	64.5	64.5	67.5		71.5	…
53	63.5	63.5	65.5	65.5	68.5		71.5	70.5
54	59.5	64.5	62.5	62.5	65.5		66.5	…
55	62.5	63.5	65.5	66.5	68.5		70.5	…
56	66.5	68.5	70.5	72.5	70.5		71.5	69.5
57	55.5	57.5	56.5	59.5	60.5		61.5	…
58	60.5	60.5	61.5	62.5	66.5		67.5	64.5

考察 混合脂肪酸へのメタノール添加時期については当初および第1週後い添加が明きらかにTsを上昇せしめる効果を現わしているが，第3および4週後の添加にはその効果が認められない。

試料皮をメタノール処理したものは，その当初に行なったものも，また毎週行なったものも共にTs上昇に役立っている。従って油脂の過酸化物がなめしに関係があるとすれば，これに対するメタノールの効果はそれを溶存させるためでなく，溶出する点にあるものといえよう。

なお，No. 46が漬なめし30日において突如82.5°CのTsを示したことは注目される。

要 約

1. この実験には油剤として，いわし油，その混合脂肪酸およびその1価アルコールエステルを，また溶剤としては軽油，ベンゼン，アセトーン，メタノール，エタノールおよびエチレングリコールを供試した。

2. 1価アルコールは他の溶剤より著しく油皮のTsを上昇せしめる結果を示した。

3. アルコールの添加はなめしの初期には明きらかに効果がある。後期には効果がない。

また連続添加する場合，第2回以後は効果がない。

4. 然るに，皮或るいは油皮の連続してアルコール処理すると，その都度Ts上昇に効果がある。

5. アルコールの効果は当初においては累加的と考えられる点もあるが，その最高Tsの点と比較すると僅差

的である。

6. なめし温度は油皮のTsより10°C以上低くすることが安全である。

7. 最高Ts 82.5°Cを示した試料があり，他一般のそれより約10°C高い。このことは，なめし条件を今一層精査する必要のあることを示すものであろう。

Food-relations among the Fish Caught by the Set-nets along the Arikawa Bay (at the Middle of the Goto Islands) during the Period from Late Autumn to Early Winter※

By

Hiroshi MAÉDA, Hirotaka MATSUOKA and Isao MATSUI

Group of the fish caught by the set-nets is, to see ecologically, consisted of not only the pelagic fish but also the demersal ones of various species distributed almost all over the possible types of food-habits to be observable in the studied area, and there are some algaevora such as *Girella punctata* and other piscivora of very high trophic levels, perhaps the end predators of this water, such as the sharks and the marlins. The catch by the set-net is, therefore, thought to be one of the most desirable materials for finding out an outline of the food-relations to be found among the fish inhabiting an area. Since we planned to find out the food-relations observable among the fish caught in an area under the strong influence of the Tsushima Current during the period from its seasonal change, the study was carried out during the period from Oct. 21 to Dec. 17 in 1956 on the catch by a group of the set-nets along the coast of the Arikawa Bay in the Goto Islands. This area is one of the most prevalent fishing ground for set-net under strong influence of the Tsushima Current without any other fishery of importance and is one of the commercial centers of these detached islands with little higher consumption of fish in the town; these made it very easy to get many facilities for the work from the staffs of the fishery cooperative society, which gratefully brought us to save much expenses to collect the stomach samples of some predators of high trophic levels and some demersal fish of high commercial value without any afraid of the possibility to sampling wrongly those from the other areas. These were the reasons why this area was selected for the study.

In this report, the records of catch compositions were first classified into 11 types by the abundant species and whether hauled up in the morning or in the evening taking the location of net and the season into consideration. Then, examining on the stomach contents of each member fish, we analyzed the food-relations found during the stay of each type of catch and found that the anchovy (*Engraulis japonica*)

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was of most ecological importance on which the arrows showing the predatory relations were concentrated. And some considerations were given to the problem what influence was led by the replacement of a certain member caught abundantly by other species of similar food-habits with similar life-form ,and to the problem what influence was led by a sudden appearance or disappearance including abrupt increase or decrease of one of the members to the food-relations of the members of the rest of it.

We are grateful to Mr. T. KAWASAKI and any other staffs of the Arikawa Fishery Cooperative Society, fishermen and fishmongers in this town for their kindness offered us carrying out this work.

Material and Method

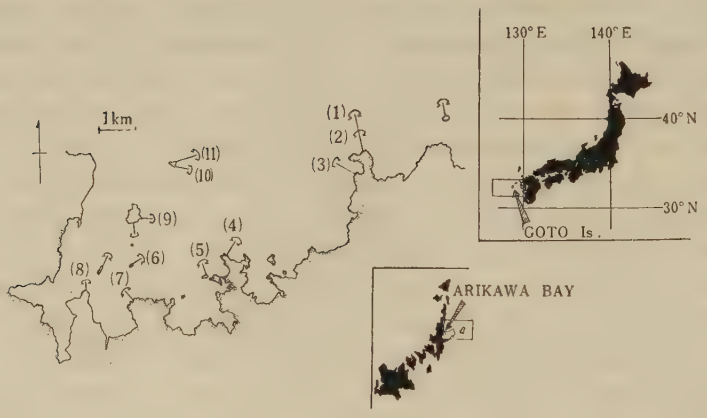

Fig. 1. Sketch chart of the Arikawa Bay.
Note : Number in parentheses indicates the net number.

There were 11 sets of the nets along the coast of the Arikawa Bay. The fish entered the nets at night were gathered at 7~9 in the morning and those entered during the daytime were hauled up at 3~5.30 in the evening. The materials used this study were collected at each haul of the nets. The fish samples of seven species of low economic value such as the round herring (*Etrumeus micropus*), *Spratelloides japonicus*, the sardine (*Sardinops melanosticta*), the anchovy (*Engraulis japonica*), the atherine fish (*Allanetta bleekeri*), the jack mackerel (*Trachurus japonicus*) and *Apogon semilineatus* were collected at fish market attaching to the cooperative society. And those hauled up in the morning (entered at night) were examined within the day, while those brought back to the market in the evening (entered during the daytime) were stored in 10 percent formalin solution and examined in the next day. For other species of high economic value, only their body sizes were measured at the

market before the auction and their stomach samples were gathered from the fishmongers twice a day, usually about 13.00 and 19.00. Then, the kinds and the weight of the organisms contained in each sample thus collected were examined; if possible in count, the individual numbers of some organisms also were included.

Results

1. Outline of the change in the catch of several fish of importance (Preliminary step to the classification of the type of catch)

As a preliminary step to this study, we intended to classify the samples into several groups according to the type of the catch compositions. It was one of the most remarkable characteristics of the catch that we could get better catch of richer species at night (hauled up in the morning) than in the daytime (hauled up in the evening). Among 41 species hauled up in the morning and 37 at night, most of the abundant species were the pelagic fish; consequently, the type of catch was strongly governed by the transit of some pelagic fish. And the summarized characteristics of the change in the catch of some abundant members are shown in the below, for reference' sake.

1) The most common and rather domestic surface swimmers around the Goto Islands and their adjucent waters : The sardines and the jack mackerel were the members of this group. These were hauled up abundantly in the morning especially at the opening part of the bay. Three species of the sardines of importance (the anchovy, the sardine and the round herring) more or less segregated their fishing ground each other and the anchovy was hauled up abundantly at the inner part while the sardine and the round herring were the characteristics of the opening part. The jack mackerel caught at the inner part and those near the opening were more or less different in size and larger individuals were inclined to be caught near the opening of the bay, while smaller ones apt to be caught at the inner part.

2) The surface swimmers with strong ability of seasonal migration : The flying fishes and the saury (*Cololabis saira*) were also the surface swimmers caught abundantly but they differed from the members of the former group in their strong ability of seasonal migration. The flying fishes are thought to be rather warmer species and visit this water in summer season. They were caught abundantly in the daytime (hauled up in the evening) during the period from before the beginning of the study to Oct. 31, and they disappeared earlier at the opening part of the bay, while stayed longer at the innermost part. The saury is known as one of the colder water inhabitants and also thought to be the fish ecologically corresponding to the flying fishes in the warmer waters in respect to their strong phototaxis, food-habits and many other habits of importance. But it passed as long as 20 days from the end of the good catch of the flying fishes to the beginning of that of the saury, moreover the saury was chiefly caught by the nets set near the opening of the bay at night in contrast with the fact that the flying fishes were caught throughout the bay and

were assumed to enter the net during the daytime. Another member of this group usually inhabiting rather colder waters was the squid (chiefly *Ommastrephes sloani pacificus*). This was caught during the latter half of the studied period chiefly near the opening part and hauled up in the morning.

3) The surface swimmers of higher trophic levels caught abundantly : The dolphin fish (*Coryphaena hippurus*) and the bonitos (*Auxis thazard, Sarda orientalis* and *Euthynnus affinis yaito*) were the members of this group. The dolphin fish was chiefly caught near the opening till November and did not show any markedly daily-rhythmic change in the catch. The good catch of the bonitos began a little before the end of that in the dolphin fish; and these fish were caught chiefly at the middle

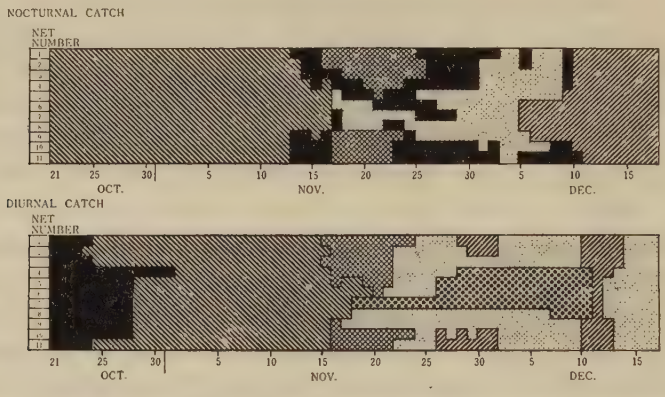
NOCTURNAL CATCH
NET NUMBER
21 25 30 5 10 15 20 25 30 5 10 15
OCT. NOV. DEC.
DIURNAL CATCH
NET NUMBER
21 25 30 5 10 15 20 25 30 5 10 15
OCT. NOV. DEC.

Fig. 2. Schematical representation of the change in the type of the catch compositions at each net with the days passing.

Nocturnal catch (hauled up in the morning)

- The dolphin fish type
- The saury, the squid and the jack mackerel type
- The dolphin fish, the bonito, the saury, the squid and the jack mackerel type
- The type of miscellaneous catch at night
- The saury, the squid and the jack mackerel type with the bonitos

Diurnal catch (hauled up in the evening)

- The flying fish type
- The dolphin fish type in the diurnal catch
- The dolphin fish, the bonito and the saury type
- The *Girella punctata* type
- The type of miscellaneous catch in the daytime
- The juvenile tuna and the bonito type

For net number, refer Fig. 1.

of the bay in the daytime.

4) *The demersal fish of importance* : *Girella punctata* was the demersal fish of importance, but this was caught mostly in the daytime at the innermost part of the bay.

5) *Temporary visitors of high trophic levels* : Few individuals of large fish of high trophic levels such as the juvenile individuals of the bluefin tuna (*Thunnus thynnus*), the marlins and the sharks were occasionally caught near the opening of the bay. Catch of the bluefin did not show any markedly daily-rhythmic change. Here, the marlin caught during the beginning half of the studied period was chiefly the striped marlin (*Makaira mitsukurii*) but this was changed into the black marlin (*Makaira mazara*) and the sailfish (*Histiophorus orientalis*) in the latter half. The shark, chiefly the hammer-head shark (*Sphyrna zygaena*), was also caught near the opening.

In consequence, the catch composition by each net during the studied period was changed considerably by the transit of the above-mentioned abundant members and the outline of the change in the catch compositions is schematically represented in Fig. 2.

2. Food-relations found in each type of the catch composition

We examined on the stomach contents of each member fish semi-quantitatively and some examples of the results are shown in Tables 1 and 2. From these tables, we will easily find, as already recorded in the introduction, that the food-habits of the members vary considerably and are distributed almost all over the possible types to be found in this water; and there are some algaevora and other piscivora, perhaps the end predators of that water. And another result of the examination on the stomach contents of worth while to be described is high rate of the occurrence of the individuals with empty stomach; but this may not mean at all that most of the individuals swimming freely have empty stomach but may well be thought to be the consequence of the vomiting due to the struggling during the hauling of the net; this prevented us very much from telling the food-habits of small fish such as the saury, the jack mackerel, the round herring, the sardine, the anchovy and *Apogon*, despite of the fact that we examined hundreds of stomach samples of each species.

Basing on the results of the examination on the stomach contents, then, we drew the schema representing the food-relations of the members in each type of the catch compositions.

Nocturnal catch (hauled up in the morning)

1) *The dolphin fish type* : This type of catch was characterized by a good catch of the dolphin fish and was found during the period from before the beginning of the study to mid-November, while this type was changed into the next one earlier at the opening of the bay but later at the innermost part.

Some attention should be paid to the following facts: (1) some fish of similar size to the dolphin fish with similar swimming ability such as the Spanish mackerel (*Scombermorus niphonius*) or the yellowtail (*Seriola quinqueradiata*) were the

Table 1. Stomach contents of each member fish caught during the stay of the dolphin fish type at night.

Stomach contents / Fish	Spanish mackerel	Yellowtail	Skipjack	Barracuda	*Ablennes anastomella*	Rizardfish	Goatfish	Puffers	*Girella punctata* (juv.)	Jack mackerel	Squids (juv.)
Sharks	1 (1000.0)		1 (19.0)	1 (200.0)					1 (240.0)		
Striped marlin		1 (6000.0)									
Sailfish								2 (140.0)			
Dolphin fish				2 (15.7)	2 (100.0)					1 (18.0)	3 (50.5)
Scombrops boops						3 (26.3)				1 (5.0)	
Barracuda										1 (1.5)	
Parapristipoma trilineatum Bastard halibut											
Red sea bream											
Hairtail											
Rizardfish											
Mackerel										1 (1.5)	
Caranx equula										1 (1.5)	
Girella punctata											
Flying fish											
Jack mackerel						5 (10.6)				1 (0.3)	4 (0.8)
Apogon semilineatus						1 (1.5)					5 (1.1)
Round herring											1 (0.2)
Spratelloides japonicus Atherine fish											

Besides, the stomach samples of the following species were examined, but we could not find any organism or its fragment contained in them :
saury (73 specimens), *Sarda orientalis* (22), *Ablennes anastomella* (21), *Formio niger* (9), scad (4), rabbitfish (3), *Auxis thazard* (2), butterfish (2), *Rachycentron canadum* (2), yellowtail (1) and filefish (1).

Bregmaceros japonicus	Round herring	Saury	Flying fishes	Anchovy	*Spratelloides japonicus*	Fish meat	Schizopod	Isopod	*Caprella*	Euphausiid	Zooplankton	Saury eggs	Seaweeds	Empty stomach	Number of individuals examined
	1 (150.0)	1 (20.0)												4	10
														1	2
		2 (220.0)												3	7
	3 (122.7)	7 (515.5)	1 (4.1)	2 (14.7)		2 (27.6)								56	80
	1 (9.5)			10 (16.5)		2 (1.5)								6	23
	5 (89.1)			5 (13.2)										2	13
				5 (63.0)		2 (25.0)			1 (0.1)					1	9
				2 (5.4)										1	3
														1	2
						1 (22.5)						1 (5.0)		0	1
				7 (43.2)										0	8
	1 (19.9)		1 (0.3)	3 (3.6)		12 (12.6)								21	39
				1 (6.6)		2 (1.4)								1	4
									10 (+)				10 (27.3)	9	19
											13 (1.6)			17	30
77 (77.2)				171 (125.3)	48 (35.1)	11 (1.2)			6 (3.9)		1 (0.1)	1 (0.2)		663	968
37 (90.1)			2 (1.4)	203 (84.8)	30 (13.6)	6 (0.7)	3 (1.8)	3 (0.4)	1 (+)	2 (0.1)				219	508
4 (0.8)				5 (0.6)	1 (0.7)					3 (-)				146	189
											3 (0.4)			0	3
						1 (+)			2 (+)					30	33

Numerals without parentheses are the numbers of the fish containing respective organisms in its stomach ; and those in parentheses are the total weight of respective organisms in the stomach of respective predators. Sign, plus in parentheses, means that the organism is present in the fish stomach but too few to weigh or less than 0.1 g.

Table 2. Stomach contents of each member fish caught during the stay of the type of miscellaneous catch in the daytime.

Fish \ Stomach contents	*Ablennes anastomella*	Conger eel	Rizardfish	Filefish	Squids (juv.)	*Bregmaceros japonicus*	Anchovy	*Spratelloides japonicus*	*Caprella*	Euphausiid	Zooplankton	Seaweeds	Empty stomach	Number of individuals examined
Sharks		1 (26.2)		1 (36.0)									2	3
Scombrops boops			1 (5.9)				1 (0.1)						7	9
Parapristipoma trilineatum			1 (12.8)				4 (83.2)	1 (21.8)					3	9
Bastard halibut							4 (36.9)						2	6
Red sea bream					1 (0.1)					1 (13.6)			1	3
Auxis thazard							7 (105.9)						60	67
Euthynnus affinis yaito							1 (1.9)						1	2
Skipjack							1 (11.3)						3	4
Seriola aureovittata (juv.)					1 (0.3)	1 (0.2)						1 (6.7)	3	6
Mackerel							2 (0.5)						3	5
Rachycentron canadum	1 (25.0)												0	1
Girella punctata									2 (+)	3 (+)		5 (13.1)	30	35
Saury										15 (37.1)			5	20
Jack mackerel							2 (0.4)		8 (1.7)		33 (6.4)		11	54
Apogon semilineatus							10 (4.4)		1 (0.1)				81	92
Sardine											1 (12.5)		1	2
Anchovy											65 (12.9)		40	105
Nemipterus virgatus						1 (4.8)							0	1

Besides, the stomach samples of the following species were examined, but we could not find any organism or its fragment contained in them : rabbitfish (6 specimens), scad (5), filefish (2), *Formio niger* (2), *Spratelloides japonicus* (2), dolphin fish (1), *Ablennes anastomella* (1), rainbow runner (1) and sunfish (1).

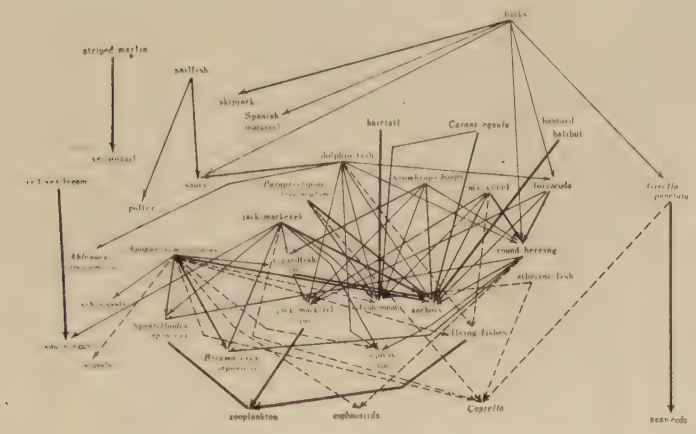

Fig. 3. Food chain observed among the fish caught during the stay of "the dolphin fish type."

Note

: More than three quarters of the stomach contents of the predator

: Neither more than three quarters nor less than two

: Neither more than two quarters nor less than a quarter

: Not more than a quarter

: observed but too few to weigh or less than a percent

important prey of the sharks or the striped marlin respectively, and this suggested the possibility to the dolphin fish being attacked more severely. But the dolphin fish, which was the sole species caught abundantly, was attacked by any of higher predators. And the dolphin fish, thus against the expectation, had not any close relation to higher predators other than the fact that the most important prey of this fish, the saury, occupied a half of the stomach contents of the sailfish and less than a quarter of that of the sharks; (2) the anchovy, on which the arrows showing the predatory relations were concentrated, was the most important prey animal throughout the members of the catch; but this fish could not be the most important prey of the dolphin fish; and (3) the dolphin fish played, thus, no important role in the food-relations against its good catch and there was no fish playing the same role in the food-relations to the dolphin fish.

2) *The saury, the squid and the jack mackerel type*: After the swimming away of the dolphin fish, there occurred another type lacking in any of the large surface swimmers of high trophic levels with strong ability of seasonal migration; and this type was characterized by a good catch of the small surface swimmers of the cold water inhabitants with strong ability of seasonal migration such as the saury and the squids. On account of the fact that the saury and the squids did not approach too closely to the coast, this type was rather characteristic of the opening part and occurred earlier and ended later at the opening part but continued only a short time at the innermost part.

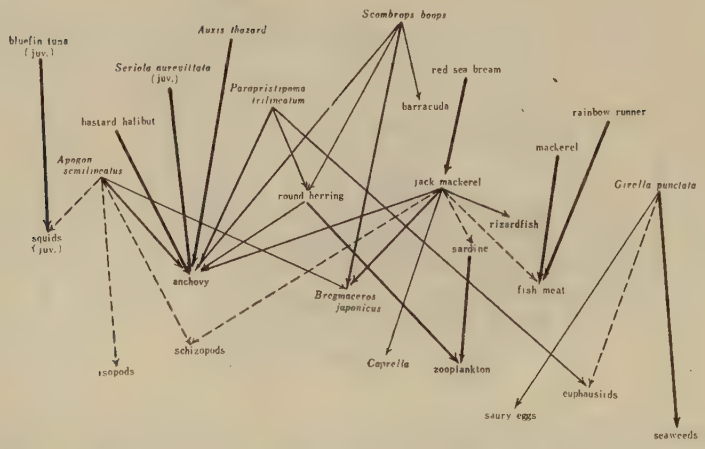

Fig. 4. Food chain observed among the fish caught during the stay of "the saury, the squid and the jack mackerel type."

The saury, which was the species caught most abundantly during this period, was not attacked by any of the predators, moreover we could not find any organism in its stomach despite of the fact that 65 specimens were examined. On the other hand, the jack mackerel, which was the next abundant species in catch, also was not attacked by any of the predators other than the red sea bream which was caught not abundantly at all; and examining 418 specimens, we found that three quarters of the catch had empty stomach and the rest of it took various animals such as the juvenile individuals of the rizardfish (*Saurus undosquamis*), *Bregmaceros japonicus*, the anchovy *etc*. These two abundantly caught members, thus, played no important role in the food-relations against the expectation from good catch together with their body sizes and the habits; and the anchovy still kept its important position in the food-relations as the prey. And it is also one of the remarkable fact that in company with the swimming away of the dolphin fish, which was the piscivore of large size, any of the predators of high trophic levels did not visit this water at all during this type of catch. We are afraid of the fact that the readers may be impressed as if there occurred some differences in the food-habits of some of the member fish from those in the type 1, but we may be aware of the fact that these differences are of insignificance but are merely apparent ones when we consider the fewness of the numbers of the individuals of some of the species examined actually.

3) *The dolphin fish, the bonito, the saury, the squid and the jack mackerel type*: In the midst of the stay of the small surface swimmers (the saury, the squids and the jack mackerel), the large surface swimmers with strong ability of seasonal migration such as the dolphin fish and the bonitos visited the part near the opening of the bay and constructed another type of catch together with the members of type 2; consequently this type was characteristic of the opening part of the bay. And this

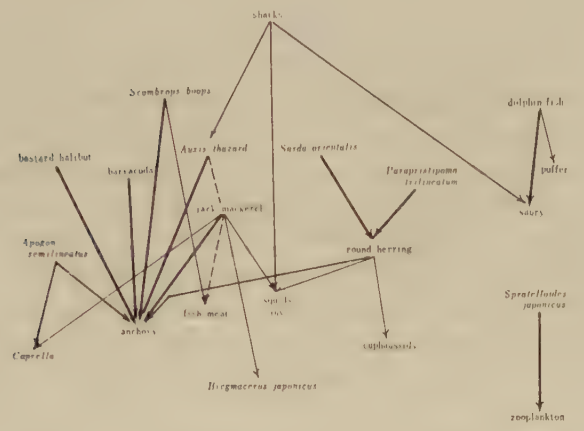

Fig. 5. Food chain observed among the fish caught during the stay of "the dolphin fish, the bonito, the saury, the squid and the jack mackerel type."

was changed again into type 2 with the swimming away of these large surface swimmers.

The fewness of the number of the species relating to one another, especially that of the primary piscivora, simplified the food-relations. It is, of course, of very interesting to tell whether or not the possible prey fish fortunately visited the water abundantly at that period such as the saury and the jack mackerel can play some of the roles of the prey fish in the food-relations such as the anchovy and the sardine when the above-mentioned possible preys were in absence or not in abundance. But the high rate of the occurrence of the individuals with empty stomach prevented us from finding out any suggestion against our aims and efforts.

Notwithstanding this, it may be also worth while to pay attention to the fact whether there were some directly predatory relations between any two of the abundant species or not, in other words, whether or not the predators such as the dolphin fish and the bonitos might visit the water because of being rich in prey fish such as the saury and the jack mackerel. But any fact supporting strongly the presence of such relations mentioned above could not be found out, *i.e.*, we could not find out any evidence suggesting the presence of the directly predatory relations between *Auxis thazard* or *Sarda orientalis* and the saury or the jack mackerel, but we found only an evidence suggesting the possibility of the presence of direct one between the dolphin fish and the saury, but we hesitate to give some significance to this fact because of the high rate of the occurrence of the individuals of the dolphin fish with empty stomach perhaps due to the vomiting during the hauling.

4) The type of miscellaneous catch at night : After the swimming away of the saury, the squids and the jack mackerel in the whole part of the bay and that of the dolphin fish and the bonitos in the opening part, none of the fish were caught

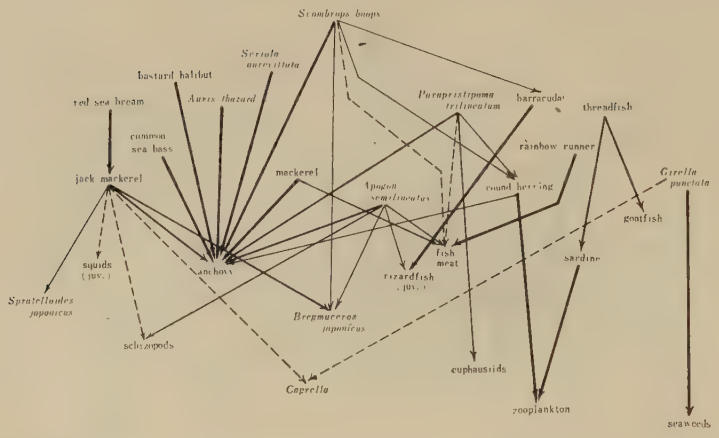

Fig. 6. Food chain observed among the fish caught during the stay of "the type of miscellaneous catch at night."

abundantly till the former three appeared again. This period of poor catch without any characteristic species was for convenience' sake represented as the type of miscellaneous catch at night.

Lack of the abundantly caught species and of high predators but richness in the number of species of the primary piscivora were the characteritics of the catch composition and the food-relations of this type of catch.

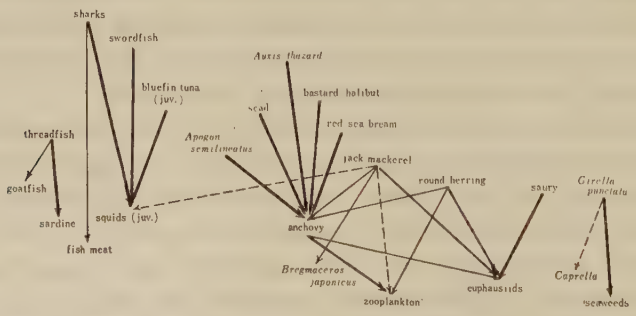

Fig. 7. Food chain observed among the fish caught during the stay of "the saury, the squid and the jack mackerel type with the bonitos."

5) *The saury, the squid and the jack mackerel type with the bonitos* : From Dec. 5 at the inner part or 5 days later at the opening part, there occurred again a good catch chiefly constituted both of the saury and the jack mackerel as the possible prey group and of the bonitos and the large individuals of the squids as the members of the predator group. This type of catch composition was called the saury, the squid

and the jack mackerel type with the bonitos and this type continued till the end of this study.

But against the expectation, any directly predatory relation could be found between the bonitos which were caught abundantly during this period and the saury which came into the bay together with the former and was thought to have a possibility of playing a role of its prey. On Dec. 17 and 18, there occurred an outbreak of euphausiids all over the bay and its adjucent waters, but any change in the food-habits of any of the member fish was induced and none of the member fish took this crustacea abundantly other than the jack mackerel, the round herring and the saury, all of which were usually found with empty stomach in other days, although we expected that the carnivora, especially those of lower orders than the primary piscivora, would have high possibility of changing into euphausiid-feeders during its outbreak.

It is also worth while to be described that high predators of large size such as the sharks, the striped marlin and the juvenile individuals of the bluefin tuna visited this water together with the occurrence in the abundant catch of *Auxis thazard*, and these three fish had directly predatory relations to the squids which also caught again abundantly during this period.

Diurnal catch (hauled up in the evening)

On account of the rareness of the migratory fish caught abundantly in the daytime (hauled up in the evening), the catch compositions in the daytime became simpler than those at night and the total catch became far poorer. And lack of higher predators than the primary piscivora was one of the most remarkable differences in the food-relations of the diurnal catch from those of the nocturnal one, although any remarkable difference in the food-habits of each member fish could not be found out.

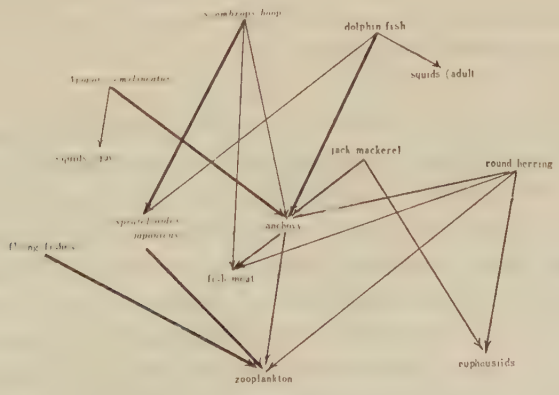

Fig. 8. Food chain observed among the fish caught during the stay of "the flying fish type."

6) *The flying fish type* : The flying fishes were caught chiefly in the daytime till Oct. 25 near the opening of the bay or till Dec. 1 at the innermost part. In consequence, there occurred another type of catch unable to be observed in the nocturnal catch and this type was represented as the flying fish type, although considerable amount of the dolphin fish capable of being regarded as one of the characteristic species was caught together with them.

The dolphin fish fed on the anchovy, but the flying fishes were not attacked by any of the predators moreover most of the individuals had empty stomach. These fishes, thus, played no important role in the food-relations, despite of the fact that they were so abundantly caught that being able to be regarded as the characteristic species and their body sizes suggested that they had high possibility of being taken by many predators.

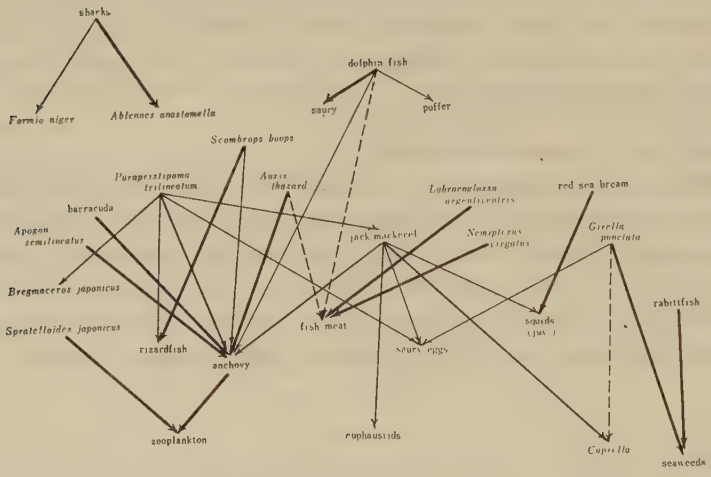

Fig. 9. Food chain observed among the fish caught during the stay of "the dolphin fish type in the diurnal catch."

7) *The dolphin fish type in the diurnal catch* : After the swimming away of the flying fishes, there succeeded to another type of catch common to the nocturnal one characterized by a good catch of the dolphin fish. A little more than 600 stomach samples being constituted of 26 species were examined, but high rate of the occurrence of the individuals with empty stomach made it very difficult to find out some successive food-relations. In consequence, we could not get any relation other than the estranged and discontinuous ones consisted of rather rich species.

8) *The dolphin fish, the bonito and the saury type* : The squids and the jack mackerel and most of the saury were caught at night and the good catch of the dolphin fish in the daytime continued five more days after the end of that at night. These facts made it impossible to be observed the type corresponding to type 2 of

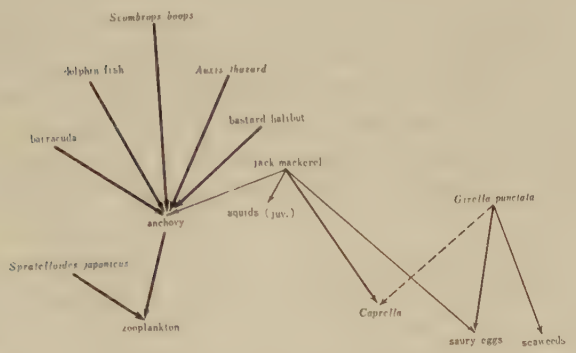

Fig. 10. Food chain observed among the fish caught during the stay of "the dolphin fish, the bonito and the saury type."

the nocturnal catch. And the part in the bay during the period occupied by type 2 in the nocturnal catch was also occupied by one of the modified types of this nocturnal one by the absence of some of the prey fish such as the jack mackerel and including small squids, and this type was represented as the dolphin fish, the squid and the saury type.

We could not clarify the presence of any relation other than simple one being constituted of rather few species. Considerable amount of the saury were caught, and this species has high possibility of playing a role of the anchovy in the food-relations as prey, but any individual or fragment of this fish could not be found out from the stomach of any fish including the dolphin fish and *Auxis thazard*, although its eggs were taken by the jack mackerel and *Girella punctata* both of which were caught not abundantly. On the other hand, we also could not find any individual of the saury with stomach containing any prey at all. The dolphin fish and *Auxis thazard*, both of which were active swimmers caught abundantly, chiefly fed on the anchovy. And any directly predatory relation, thus, could not be found out between the abundantly caught species; and from the food-relational point of view, the saury was well thought to be one of the independent visitors from others against the expectation. The anchovy still kept its importance in the food-relations in respect to the fact that the arrows showing the predatory relations were concentrated on this species. The anchovy was attacked by the dolphin fish and *Auxis thazard*. The barracuda, *Parapristipoma trilineatum* and *Apogon semilineatus* in type 2 and the barracuda, *Scombrops boops* and the bastard halibut of this type took the anchovy. Therefore, it is thought to be very interesting to examine whether or not we could not find any evidence suggesting the possibility of the presence of the repulsive relation of catch among these fish taking the common prey. And we examined carefully the catch records from this point of view, but unfortunately we could not find any suggestion for this problem chiefly because of severe and irregular deviations and some uncertainty in the catch records of such species of the auxiliary catch.

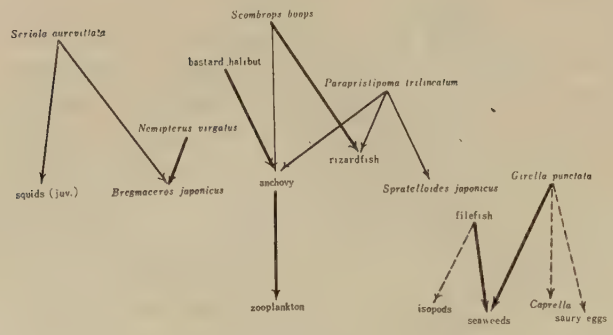

Fig. 11. Food chain observed among the fish caught during the stay of "the *Girella punctata* type."

9) *The Girella punctata type* : Good catch of the algaevora was one of the most remarkable characteristics of the catch compositions during the daytime. And considerable amount of one of the demersal and diurnal algaevora, *Girella punctata*, were caught in the daytime chiefly by the net set at the innermost part of the bay during the period from Nov. 15 to Dec. 10. A good catch of this fish characterized another type of catch specific to the innermost part in the daytime. This type of catch was represented as *Girella punctata* type.

During the continuation of this type of catch, we could not find any relation but very simple ones being constituted of very few species, and this was partly thought to be due to the absence of pelagic fish so abundantly caught as capable of being ranked as characteristic species and due to the poorness of the fish fauna caught in the daytime, which was also one of the general characteristics of the diurnal catch.

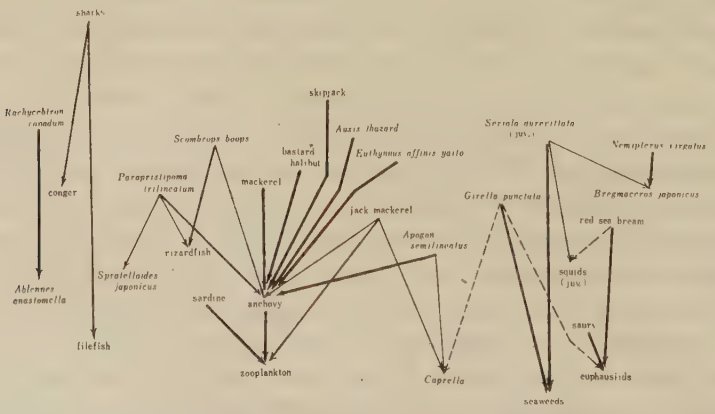

Fig. 12. Food chain observed among the fish caught during the stay of "the type of miscellaneous catch in the daytime."

10) The type of miscellaneous catch in the daytime : During the period from Nov. 20 to the end of this study, we could not find out any of the fish caught abundantly other than the saury, the squids and the jack mackerel. But these fish were all caught at night, and we could catch plentifully none of the fish else than *Girella punctata* in the innermost part and occasionally the bonitos and the juvenile individuals of the bluefin tuna. This period of poor catch without any characterizing species was for convenience' sake represented as the type of miscellaneous catch in the daytime.

For the outline of the food-relations, no fact but those described already in type 7 was able to be found out. And like the nocturnal catch any remarkable change in the food-habits of any of the member fishes was not induced by the outbreak of euphausiids on Dec. 17 and 18.

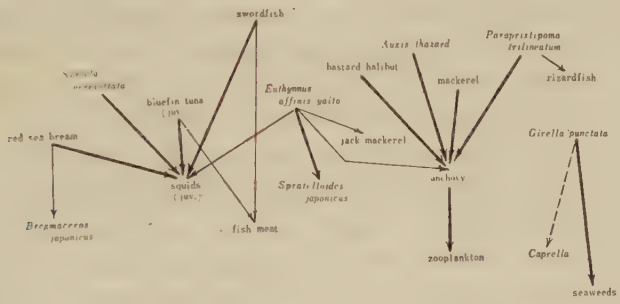

Fig. 13. Food chain observed among the fish caught during the stay of "the juvenile tuna and the bonito type."

11) The juvenile tuna and the bonito type : Plentiful individuals of the bonitos with the juvenile bluefin tuna were caught on Nov. 30 and Dec. 12 or thereabout chiefly near the opening part of the bay; this fact and the absence of any other species caught abundantly during this period in this water made us possible to observe one of the types of the catch represented as the juvenile tuna and the bonito type.

Poorness of the fish fauna and high rate of the occurrence of the individuals with empty stomach made it very hard to find out any complicated relation of some significance; and we want to describe here only the fact that there was high possibility of supporting that the anchovy and the small squids were the important animals from the food-relational point of views.

Discussion

It may well be said, from the above-mentioned results, that among the group of fish caught by the set-nets and the animals eaten by them the anchovy was the most important species in the food-relations as prey, on which the arrows showing the

predatory relations were concentrated.

The saury and the jack mackerel, which were caught abundantly showing severe deviation, were expected to have high possibility of playing some parts of the role of the anchovy in the food-relations as prey; but high rate of the occurrence of the individuals of each species with empty stomach perhaps due to the vomiting during the hauling prevented us very much from getting sufficient evidence in support of the affirmative conclusion of the food-habits of the fish especially their quantitative recognition. In consequence, we could neither find out any sufficient evidence suggesting the possibility of these fish taken by predators instead of the anchovy nor find the possibility of taking abundantly the common prey to the anchovy. On the other hand, the large surface swimmers such as the dolphin fish and the bonitos repeated some transit during the studied period, but each of them did not have any close relation to other animals in the water in respect to the food-relational point of views. Moreover, we could not find out any evidence strongly supporting the possibility of the presence of the directly predatory relation between these large surface swimmers and the possible prey fish coming together with them, although we also could not find out any fact clearly denying such a possibility.

We are obliged to conclude nothing but the fact that, despite of our aims and considerable efforts, we unfortunately could not get clear and sufficient evidence in support of or denial of the suggestion that these visitors were not the independent ones but had close relations with each other or with the demersal fish.

And sufficient evidence supporting the clearly daily rhythmic change in the food-habits of any of the member fish could not be found out, but richer fish fauna caught at night than in the daytime caused the food chain of the nocturnal catch constituted of much steps of the links than in the diurnal one. And we could fortunately observed the food-relations of the fish which extended from the fish of so low food ranks as the algaevora such as *Girella punctata* to the secondary piscivora or higher ones perhaps including the end predators of the sea such as the sharks and the marlins.

It is thought to be of very importance to examine whether or not we can find out any evidence suggesting the possibility of the presence of the repulsive relations in the catch between the large surface swimmers with strong ability of seasonal migration and the demersal fish taking the common food to them, but we could not find out any clear suggestion chiefly because of severe and irregular deviations and partly of some uncertainty in the catch records of the auxiliary species.

LARKIN (1956) pointed out that the relatively wide flexibility of food-habits and the breadth at each level of the food chain rather than hight of pyramid of number were the most remarkable characteristics of fresh-water fish communities. But, in our case, in the marine environment, we could not find any evidence supporting the flexibility of food-habits of the fish but could find out many facts suggesting the rigidity of the food-habits of the fish and the importance of the anchovy in the food-relations was not suffered from any influence by the transit of some possible prey

perhaps forming some huge schools. Furthermore, some possibility of the rigidity of the food-habits of the primary piscivora, which usually took chiefly such small fish as the anchovy and *Bregmaceros japonicus* and were expected to have some possi-

Supplemental Table. Name of the fish used in the present study.
1) Science name and Japanese one of the fish described in the common name.

Common name	Science name	Japanese name
Anchovy	*Engraulis japonica*	Katakuchi-iwashi
Atherine fish	*Allanetta bleekeri*	Tougoro-iwashi
Barracuda	*Sphyraena japonica*	Kamasu
Bastard halibut	*Paralichthys olivaceus*	Hirame
Black marlin	*Makaira mazara*	Kurokawa
Bluefin tuna	*Thunnus thynnus*	Maguro
Butterfish	*Pampus argenteus*	Managatsuwo
Common sea bass	*Lateolabrax japonicus*	Suzuki
Dolphin fish	*Coryphaena hippurus*	Shiira
Filefish	*Stephanolepis cirrhifer*	Kawahagi
Flying fishes	Exocoetidae	Tobiuwo
Goatfish	*Upeneus bensasi*	Himeji
Hairtail	*Trichiurus lepturus*	Tachiuwo
Hammer-head shark	*Sphyrna zygaena*	Shumokuzame
Jack mackerel	*Trachurus japonicus*	Ma-aji
Mackerel	*Pneumatophorus japonicus*	Ma-saba
Puffers	Tetraodontidae	Fugu
Rabbitfish	*Siganus fuscens*	Aigo
Rainbow runner	*Elagatis bipinnulata*	Tsumuburi
Red sea bream	*Chrysophrys major*	Ma-dai
Rizardfish	*Saurus undosquamis*	Ma-eso
Round herring	*Etrumeus micropus*	Urume-iwashi
Sailfish	*Histiophorus orientalis*	Basho-kajiki
Sardine	*Sardinops melanosticta*	Ma-iwashi
Saury	*Cololabis saira*	Sanma
Scad	*Decapterus muroadsi*	Muro-aji
Skipjack	*Katsuwonus pelamis*	Katsuwo
Spanish mackerel	*Scomberomorus niphonius*	Sawara
Striped marlin	*Makaira mitsukurii*	Ma-kajiki
Sunfish	*Mola mola*	Manbo
Swordfish	*Xiphias gladius*	Me-kajiki
Threadfish	*Alectis cilialis*	Itohiki-aji
Yellowtail	*Seriola quinqueradiata*	Buri

Note :
bonitos : used for representing *Auxis thazard*, *Euthynnus affinis yaito* and *Sarda orientalis* as a whole, but to indicate each of them the science name is employed.
sharks : chiefly hammer-head shark but usually used including all other ones.

bility of taking small crustacea swimming in the bottom layer, was pointed out. That is to say, we observed an outbreak of the euphausiids all over the bay and its adjucent waters on Dec. 17 and 18 but none of the fish of this group clearly took this crustacea, although we found an evidence suggesting that this outbreak was attacked by the jack mackerel, the round herring and the saury all of which were usually found with empty stomach. For the hight of the number of pyramid in the marine environment, we wish to consider that it is never low but rather high even in such an on-shore water as this, although we should pay heed to the fact that this water is very close to the coast but is under strong influence of an oceanic current.

2) Japanese name of the fish described in the science name.

Science name	Japanese name
Ablennes anastomella	Datsu
Apogon semilineatus	Nenbutsu-dai
Bregmaceros japonicus	Saiuwo
Caranx equula	Kaiwari
Formio niger	Kuroajimodoki
Girella punctata	Mejina
Labracoglossa argentiventris	Takabe
Nemipterus virgatus	Itoyori-dai
Parapristipoma trilineatum	Isaki
Rachycentron canadum	Sugi
Scombrops boops	Mutsu
Seriola aureovittata	Hiramasa
Spratelloides japonicus	Kibinago

Summary

1). Food-relations observed during the period from Oct. 21 to Dec. 17 in 1956 on the groups of the fish caught by 11 set-nets along the coast of the Arikawa Bay were analyzed, for the purpose of finding out an outline of the food-relations observed among the fish caught in an area under strong influence of the Tsushima Current during the period of its seasonal change.

2). Since we expected that the food-relations might differ with the fish fauna consequently with the catch composition which were strongly governed by the transit of some pelagic fish, we treated of the samples classifying into 11 types as represented schematically in Fig. 2 based not exclusively on the catch compositions but also on the fact whether hauled up in the morning or in the evening considering together with the location and the seasons.

3). The food-relations observed in each of 11 types of catch compositions are shown in Figs. 3~13. And we found that the anchovy was the most important fish

in the food-relations and the arrows showing the predatory relations were concentrated on this fish.

4). Special attention were paid to the problems whether or not the possible prey fish visited the water abundantly at each period can play some of the role of the prey fish which were taken by many fish when the formers were in absence or not in abundance, what kinds of relations were observable between the large fish sometimes visited the water abundantly and other ones caught more or less regardless of the richness or poorness of the catch of the formers, and also to the problems whether or not the large surface swimmers visited the water having directly predatory relations to the possible prey fish coming together with them.

5). But against our aims and efforts, we could, unfortunately, not get any clear and sufficient evidence in support of or denial of the suggestion that these visitors were not the independent ones but had close relations with each other or with the fish caught regardless of their transit.

6). It was pointed out by LARKIN (1956) that the relatively wide flexibility of the food-habits and the breadth at each level of the food chain rather than hight of the pyramid of number were the most remarkable characteristics of fresh-water fish communities. But in the marine environment, we want to consider that the food-habits of the marine fish are not so flexible but rather rigid, and for the hight of the pyramid, we want to consider that it is never low but rather high even in such an on-shore water as this, although we should pay heed to the fact that this water is very close to the coast but is under strong influence of an oceanic current.

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Morphometric Characters of Yellowfin Tuna, *Neothunnus albacora* (LOWE), in the Southwestern Waters of the Indian Ocean (off the Southwest of the Madagascar Island)※

By

Saburo TSURUTA

Introduction

Our previous reports[1,2] were concerned with the morphometric features of yellowfin tuna caught in the eastern and northwestern waters of the Indian Ocean. Present report presents the results of our research in series on yellowfin tuna samples obtained in the southwestern waters of the Indian Ocean (off the southwest of the Madagascar Island), in an attempt to clarify their morphometric characters.

Identification of the species by a statistical study of morphometric characters was initiated by FISHER (1930). This method has been applied by many other workers to ichthyology. The results of their researches have led to the belief that the yellowfin tuna migrates only in limited ranges, and that no major intermigration occurs among their schools. SCHAEFER[3] (unpublished) has pointed out that a superior method is required for statistical analyses. However, to those whose objective is to compare tuna caught in the waters widely apart from each other, it seems impractical to conduct any more accurate analyses. I have endeavoured at collection of samples in an effort to gain measurement values identical with that of our large samples, yet I have still to find a method with which to determine whether our collections are of the typical species or not. Provided that our present samples are of the typical species, I must first give descriptions of yellowfin tuna schools in the waters and at the time when our samples were collected. This, at once, is the purpose of our present study.

Data and Method

Present sample was obtained from among yellowfin tuna caught with tuna longline by the crew of the fisheries training ship, *Koyo-Maru*, of the Shimonoseki College

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of Fisheries during the period from January lst to 13th, 1961, in the southwestern waters of the Indian Ocean (position approximately 31°—46° E long., 29°—39° S lat.; see Fig. 1). After removing those in postmortum rigor I have got 78 samples. The external morphometric characters were estimated by the usual method. Data are shown in Table 1. I should hereby like to extend my sincerest appreciation to all crews and cadets of the *Koyo-Maru* for their willing cooperation in morphometric measurements carried out this work.

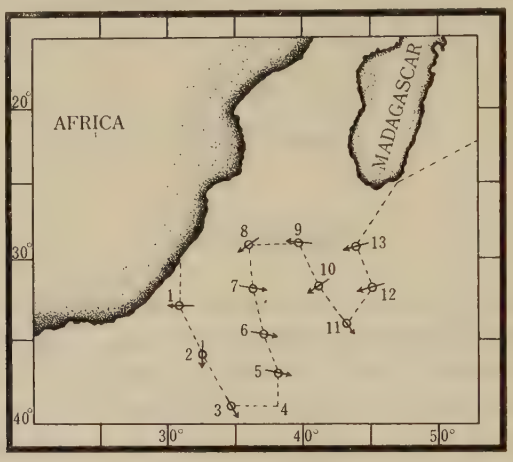

Fig. 1. Tuna longline fishing ground; operational course line, 12 setting positions and direction and date (Jan. 1~13 in 1961).

Table 1. Morphometric measurements of yellowfin tuna from the southwestern waters of the Indian Ocean, Jan. 1~13, 1961.

Body length	Head length	Insertion I.D.F.	Insertion II.D.F.	Insertion A.F.	Height of II.D.F.	Length of P. F.	Height of A. F.	Greatest body depth	Greatest body width	Body weight	Sex
cm	cm	cm	cm	cm	cm	cm	cm	cm	cm	lbs	
78	22	23	44	45	13	21	14	19	15	24	M
79	22	23	42	47	13	23	13	19	13	22	M
81	23	23	43	48	11	21	13	20	14	22	M
82	23	24	45	48	13	22	14	21	17	31	M
115	31	34	62	70	28	33	27	24	——	90	F
117	32	34	63	71	25	31	27	28	——	77	F
119	31	30	58	70	22	27	23	29	22	75	F
120	32	33	67	68	24	29	29	31	23	84	M
121	32	36	66	72	26	30	28	31	25	84	M
121	34	34	66	74	31	32	33	32	26	101	F

121	33	34	64	71	26	29	27	33		90	M
121	32	34	64	72	26	28	27	32	23	88	F
121	31	32	64	71	27	32	32	32	25	95	F
122	33	32	62	72	34	32	39	32		90	M
122	33	34	65	70	32	32	34	31	24	90	F
123	33	36	63	72	34	32	35	32		106	F
123	31	33	64	70	26	30	32	30		84	M
124	33	33	64	73	30	31	35	32	25	95	M
124	33	35	64	73	26	23	30	33	- -	97	F
124	33	35	66	72	23	30	27	31	24	93	F
125	33	36	64	77	28	29	30	33	24	94	M
125	32	36	67	73	29	29	31	32	24	93	M
125	34	37	66	73	29	28	27	28	22	85	F
125	32	37	66	74	31	31	34	34	- -	94	F
125	34	37	67	76	28	34	27	33	26	104	M
125	33	35	63	71	27	30	34	34	25	99	F
125	32	34	65	70	33	30	34	32	26	97	F
126	33	36	65	73	31	31	32	31	25	90	F
126	32	37	67	75	28	29	30	32	25	99	F
126	33	34	64	71	28	31	29	33	25	93	F
126	32	34	65	72	26	28	25	31	24	95	F
126	33	35	67	72	31	31	29	33	23	99	F
127	34	33	65	74	33	33	35	32	23	99	M
127	33	32	64	73	29	31	32	31	25	99	F
128	32	34	67	72	30	33	32	32	26	97	F
128	34	34	67	73	30	32	33	33	25	99	M
129	34	34	67	73	29	31	27	33	—	103	F
129	34	37	71	74	26	30	27	34		110	M
129	33	35	69	74	30	30	31	34	27	106	M
129	33	35	67	74	25	32	28	31	28	96	F
129	33	34	67	73	34	32	36	34	27	112	M
130	33	36	66	72	33	32	37	31	- -	101	F
130	34	37	67	73	30	32	23	33	—	101	M
130	33	36	67	74	24	29	27	32		93	M
131	35	39	71	76	33	30	36	30		76	F
131	34	34	68	78	28	29	28	33	25	112	M
131	34	38	69	75	36	36	37	32	28	104	F
131	33	33	66	73	35	35	37	31	25	101	F
132	33	39	68	77	31	33	33	35	27	115	F
133	34	37	69	75	34	31	36	35	27	115	M

133	35	35	68	77	40	35	43	32	26	119	F
134	35	38	71	77	42	32	35	33	26	114	F
135	34	37	67	75	38	33	43	34	21	108	F
135	36	35	67	75	41	34	41	35	27	115	M
136	36	35	69	80	41	33	46	36	——	99	F
136	36	40	72	79	44	31	49	36	——	119	F
138	34	39	70	77	39	30	42	35	——	115	F
138	35	40	68	77	30	31	29	36	27	119	M
138	36	38	71	76	65	33	52	37	——	135	F
138	35	35	69	78	38	32	41	35	28	124	F
139	35	38	70	79	35	34	48	32	——	119	F
139	34	37	72	79	37	32	40	35	——	119	F
139	34	37	69	77	45	32	47	35	28	126	F
140	34	38	73	81	71	32	71	37	30	141	F
141	37	39	72	82	40	35	51	35	26	124	F
141	37	37	74	81	44	33	49	37	——	141	F
141	36	37	72	79	47	35	54	33	27	124	F
142	38	42	76	82	52	34	62	33	——	111	F
142	35	38	71	78	41	33	37	35	19	115	M
143	37	39	76	79	45	34	51	35	27	137	F
143	39	39	72	90	35	31	44	37	27	137	F
144	37	37	73	82	44	34	50	33	25	130	F
145	38	35	72	80	67	33	67	40	——	154	F
147	40	40	76	82	49	32	57	39	——	130	M
147	37	39	74	82	51	34	45	39	28	154	M
150	37	40	78	84	45	35	53	36	27	148	F
151	38	39	75	83	36	35	55	40	——	161	M
155	40	42	81	86	54	33	34	40	29	174	M

Growth-rate of Yellowfin Tuna in the Southwestern Waters of the Indian Ocean

From Table 1, we obtained data as in Table 2, by the usual statistical calculation method.

The rate of growth of yellowfin tuna in various parts of the waters in discussion from the stage when the body length is 100 cm to the stage when it has grown to 150 cm is, as shown below, much the same as with yellowfin tuna in the other waters, being the greatest in the height-increment on the second dorsal fin and anal fin, and the smallest in the length on the pectoral fin.

1. Head length: 36.2% (276 mm—386 mm)
2. Distance from tip of snout to insertion of first dorsal fin: 41.5% (282 mm—399 mm)
3. Distance from tip of snout to insertion of second dorsal fin: 35.0% (557 mm—752 mm)

Table 2. Statistics of linear regression of measurements of yellowfin tuna, *Neothunnus albacora* in the southwestern waters of the Indian Ocean (Jan. 1—13, 1961).

Independent variable (x)	Dependent variable (y)	N	x	y	Sx^2
Total length	Head length (cm)	78	129	34	15,759
Do.	Insertion of Ⅰ. D. F. (cm)	78	129	35	15,759
Do.	Insertion of Ⅱ. D. F. (cm)	78	129	67	15,759
Do.	Insertion of A. F. (cm)	78	129	74	15,759
Do.	Greatest body depth (cm)	78	129	33	15,759
log Total length	Length of P. F. (cm)	78	2.1105897	31	0.2878738
Do.	*log* Height of Ⅱ. D. F. (cm)	78	2.1105897	1.5314789	0.2878738
Do.	*log* Height of A. F. (cm)	78	2.1105897	1.5563025	0.2878738
Do.	*log* Body weight lbs.	78	2.1105897	2.0086002	0.2878738

Sy^2	Sxy	b	a	s
852	3,486	0.221207	5.46	1.020
1,078	3,698	0.234660	4.73	1.663
3,570	6,155	0.390572	16.62	3.918
4,454	8,072	0.512215	7.92	2.053
1,190	4,125	0.261755	− 0.77	1.204
713	12.076947	41.952222	−57.54	1.648
1.6533089	0.576251	2.001749	− 2.6933913	0.08108
1.6789392	0.574203	1.994634	− 2.6535506	0.08378
1.9891603	0.688868	2.392951	− 3.0499369	0.06696

4. Distance from tip of snout to insertion of anal fin: 43.5 % (591 mm—848 mm)
5. Greatest body depth: 51.6 % (254 mm—385 mm)
6. Height of second dorsal fin: 125.5 % (204 mm—460 mm)
7. Length of pectoral fin: 28.0 % (264 mm—338 mm)
8. Height of anal fin: 124.0% (217 mm—486 mm)
9. Body weight: 164.2 % (55.4 lbs—143.7 lbs)
10. Ratio of sexes: male 37.2 %, female 62.8 %

Equations of regression needed for the above calculations were obtained from Table 2 and are shown below:

1. Head length y on total length x : $y=0.221207\ x+5.46$
2. Snout to insertion of first dorsal fin y on total length x : $y=0.234660\ x+4.73$
3. Snout to insertion of second dorsal fin y on total length x : $y=0.390572\ x+16.62$
4. Snout to insertion of anal fin y on total length x : $y=0.512215\ x+7.92$
5. Greatest body depth y on total length x : $y=0.261755\ x-0.77$
6. Length of pectoral fin y on total length x : $y=41.952222\ x-57.54$
7. Height of second dorsal fin y on total length x : $y=0.00202586\ x^{2.001749}$
8. Height of anal fin y on total length x : $y=0.00222049\ x^{1.994634}$
9. Body weight y on total length x : $y=0.000891381\ x^{2.392951}$

Comparison

1. Head length

The samples with body length of about 100 cm measure 276 mm in the head length, which is longer than yellowfin tuna's of corresponding sizes in any other waters. The length indicates the greatest difference when compared with the Hawaiian sample and the mid-Indian Ocean sample, being 18 mm larger than that of the former and 7 mm than that of the latter, respectively. Little differences are noted from samples of the other waters. The samples with body length of 150 cm measure 386 mm in the head length, which is 15 mm longer than that of the Hawaiian's but much the same as that of the samples of the other waters. However, the rate of the head length-increment of the samples in the range from 100 cm to 150 cm in body length is smaller than that of the other waters, being a little over 36 percent. It may be said that head length is, in general, relatively small in large samples. Table 3 shows these computed values.

2. Distance from tip of snout to fin insertions

(1) **Distance from tip of snout to insertion of first dorsal fin** : The samples with body length of 100 cm and 150 cm measure 282 mm and 399 mm in the distance respectively, which is both shorter than that of any other waters; and this is 24 mm shorter with the 100 cm sample and 37 mm shorter with the 150 cm one than that of the mid-Indian Ocean samples, and also is 17 and 38 mm shorter than that of the southwest of the Greater Sunda Islands one. The great differences also indicate in this distance from samples of the other waters than in the case of the head length. The rate of the distance-increment of the samples in the range from 100 cm to 150 cm in body length is slightly over 41 percent, which is greater than the southwest Pacific's, but a little smaller than that of the other waters. Table 3 shows these computed values.

(2) **Distance from tip of snout to insertion of second dorsal fin** : The samples with body length of 100 cm measure 557 mm in the distance, which is longer than that of any other waters ; and this is 43 mm longer than that of the Hawaiian's. The samples with body length of 150 cm measure 752 mm in the distance which is a little longer than that of the southwest Pacific and the Hawaiian's, but shorter than that of the other waters, and this is 23 mm shorter than that of the mid-Indian Ocean's. It may be said, therefore, with the small specimens in this water, the distance between the first and second dorsal fins is longer than that of the other waters. However, the rate of the distance-increment of the samples in the range from 100 cm to 150 cm in body length is slightly over 35 percent. This, as in the case of the head length, is smaller than that of any other waters. Table 3 shows these computed values.

(3) **Distance from tip of snout to insertion of anal fin** : The samples with body length of 100 cm measure 591 mm in the distance, which is 21 mm shorter than that of the southwest Pacific's, but longer than that of the other waters, which is 22 mm longer in the distance than the Hawaiian's and 19 mm longer than the

samples of the southwestern waters of the Greater Sunda Islands. With the 150 cm sample, this measures 848 mm in the distance, which is 8 mm shorter than that of the Costa Rican's, but longer than that of the other waters, and also which is 22 – 25 mm longer in the distance than that of the samples of the southwest Pacific, Hawaii and the southwestern waters of the Greater Sunda Islands. The rate of the distance-increment of the samples in the range from 100 cm to 150 cm in body length is a little over 43 percent. This, as in the case of 2 (1), above, is greater than that of the southwest Pacific's, but slightly smaller than that of the other waters. Table 3 shows these computed values.

3. Greatest body depth

The samples with body length of 100 cm measure 254 mm in the depth, which is 26 mm and 17 mm larger than that of the southeast Arabian Sea and the mid-Indian Ocean's, respectively, but smaller than that of the other waters, and in comparison with the southwest Pacific's, which is 17 mm smaller. With the 150 cm sample, this measures 385 mm in the depth, which is 10 mm smaller than that of the Angola's, but 24 mm and 13 mm larger than that of the southwest Pacific and southeast Arabian Sea's, respectively. The rate of the depth-increment of the samples in the range from 100 cm to 150 cm in body length is slightly over 51 percent, which is smaller than that of the southeast Arabian Sea and the mid-Indian Ocean's, but greater than that of the other waters. Table 3 shows these computed values.

4. Height and length of fins

(1) Height of second dorsal fin : The samples with body length of 100 cm measure 204 mm in the height, which is 84 mm lower than that of the southwest Pacific's, but 46 mm greater than that of the Costa Rica's. With the 150 cm sample, this measures 460 mm in the height, which is 95 mm lower than that of the sample of the southwestern waters of the Greater Sunda Islands and 88 mm smaller than that of the southwest Pacific sample, but 145 mm greater than that of the Costa Rica's. The rate of the height-increment of the samples in the range from 100 cm to 150 cm in body length is slightly over 125 percent, which is smaller than that of the samples of the southwestern waters of the Greater Sunda Islands, Hawaii and the southeast Arabian Sea, but greater than that of the other waters. Table 3 shows these computed values.

(2) Length of pectoral fin : The samples with body length of 100 cm measure 264 mm in the length, which is considerably shorter than that of any other waters, but is 54 mm shorter in length than the southwest Pacific's. With the 150 cm sample, this measures 338 mm in the length, which is shorter, as in the case of the 100 cm sample, than that of any other waters, but 41 mm and 36 mm shorter in length, respectively, than that of the Hawaiian and Angola's. The rate of the length-increment of the samples in the range from 100 cm to 150 cm in body length is a little over 28 percent, which is smaller than that of the Angola and Costa Rican samples, but greater than that of the other waters. This rate of the length-increment is approximately twice as large as that of the southwest Pacific and

the mid-Indian Ocean's. Table 3 shows these computed values.

(3) Height of anal fin : The samples with body length of 100 cm measure 217 mm in the height, which is 81 mm lower than that of the southwest Pacific's and 7 mm lower than that of the sample of the southwestern waters of the Greater Sunda Islands, but 46 mm higher than that of the Costa Rican's. With the 150 cm sample, this measures 486 mm in the height, which is 129 mm and 58 mm higher than that of the Costa Rican and Angola's, respectively, but 161 mm lower than that of the southwest Pacifc's. The rate of the height-increment of the samples in the range from 100 cm to 150 cm in body length is a little over 124 percent, which is greater than that of the Costa Rican and the southwest Pacific's, but considerably smaller than that of the samples of the southwestern waters of the Greater Sunda Islands and the mid-Indian Ocean. Table 3 shows these computed values.

5. Body weight

The samples with body length of 100 cm measure 54.4 lbs in the body weight, which is heavier than that of any other waters, but 14.4 lbs heavier than the Costa Rican's. With the 150 cm sample, this measures 143.7 lbs, which is slightly lighter than that of the southeast Arabian Sea's and much same as the Hawaiian's, but the weight is approximately 12 lbs heavier than that of the Costa Rican and the mid-Indian Ocean samples. The rate of the weight-increment of the samples in the range from 100 cm to 150 cm in body lengfh is a little over 164 percent, which is slightly smaller than that of the southwest Pacific and the mid-Indian Ocean's, and considerably smaller than that of the other waters. Table 3 shows these computed values.

Table 3. Comparison of morphometric characters between the SW of the Indian Ocean samples and those of samples from the other waters at each 100 cm and 150 cm in body length.

Item		SW of the Indian Ocean	Middle of the Indian Ocean	SE of the Arabian Sea	SW of the Greater Sunda Is.	SW of the Pacific Ocean	Hawaiian waters	Costa Rica	Angola
Head length	A	276 mm	− 7 mm	—— mm	− 3 mm	− 2 mm	−18mm	− 3 mm	− 4 mm
	B	386 mm	− 1 mm	—— mm	+ 4 mm	− 6 mm	−15mm	+ 4 mm	− 2 mm
	C	36.2 %	43.1 %	—— %	42.9 %	38.7 %	43.8 %	42.9 %	41.2 %
Snout to insertion of 1st dorsal fin	A	282	+24	+18	+17	+17	+ 6	+13	+13
	B	399	+37	+29	+38	+ 5	+13	+28	+17
	C	41.5	42.5	42.7	46.2	35.5	43.1	44.7	41.0
Snout to insertion of 2 nd dorsal fin	A	557	−28	−31	−22	−16	−43	−31	−28
	B	752	+23	+15	+ 3	− 9	− 4	+13	+ 6
	C	35.0	46.5	45.8	41.1	37.3	45.5	45.4	43.3
Snout to insertion of anal fin	A	591	− 6	——	−19	+21	−22	− 2	− 9
	B	848	−10	——	−22	−25	−24	+ 8	−16
	C	43.1	43.2	——	44.4	34.5	44.8	45.3	43.0

Greatest body depth	A	254	−17	−26	+ 3	+17	0	+ 1	+ 7
	B	385	− 7	−13	− 2	−24	− 4	− 2	+10
	C	51.6	59.5	63.2	49.0	33.2	50.0	50.2	51.3
Height of 2nd dorsal fin	A	204	——	−29	− 3	+84	−28	−46	−28
	B	460	——	−38	+95	+88	−23	−145	−81
	C	125.5	——	141.1	176.1	90.3	142.6	100.1	116.4
Length of pectoral fin	A	264	+39	——	+30	+54	+28	+ 6	+15
	B	338	+11	——	+21	+25	+41	+10	+36
	C	28.0	15.2	——	22.1	14.2	26.4	28.9	34.1
Height of anal fin	A	217	−34	——	+ 7	+ 81	−20	− 46	−27
	B	486	+16	——	+155	+161	+13	−129	−58
	C	124.0	174.3	——	186.2	117.1	153.3	108.8	125.3
Body weight	A	lbs 54.5	lbs −8.6	lbs −9.1	lbs −11.4	lbs −4.4	lbs −11.4	lbs −14.4	lbs ——
	B	lbs 143.7	lbs −11.6	lbs +6.5	lbs −5.6	lbs −9.4	lbs +0.2	lbs −11.7	lbs ——
	C	164.2%	188.4%	231.6%	220.9%	168.0%	234.9%	230.0%	—— %

Note : A and B are body length 100 cm and 150 cm but C is growth rate (%).

6. Ratio of sexes and morphometric differences

(1) Ratio of sexes : According to sexes, sorting was made of the 98 yellowfin tuna without 13 failed to the measure and 5 dameged by sharks in a total catch of 116; and among these, 38 (39%) were male and 60 (61%) female. However, of those caught in the southern waters (near 37° E long., 34° S lat.), almost all were female. As we proceeded northward, the number of males increased, but the majority were still ocupied by females. The most samples occured with gonads of the earliest stage, but a few females were seemed to be the second stage.

(2) Morphometric differences between male and female : The following differences among male and female were detected from Table 1 by the same calculation method applied as to produce Table 2. HIRANO and TAGAWA[4] reported that no external differences are noted between male and female, and that the male is a little larger than the female only in the average greatest body depth. This is also the case of our samples, but we have also noted some other differences.

1) Head length : The 100 cm samples measure 274 mm in the head length both for male and female. The 150 cm samples do 387 mm in the head length, which is 7 mm longer than that for female. Therefore, the rate of the head length-increment of the samples in the range from 100 cm to 150 cm in body length is greater for male than female, being about 41 percent for the former and about 39 percent the latter. Equations of regression are given below and Table 4 showing these computed values.

$y = 0.226011\ x + 4.75$ ..... Male

$y = 0.211134\ x + 6.34$ ..... Female

2) Distance from tip of snout to fin insertions:

(i) **Distance from tip of snout to insertion of first dorsal fin** : The 100 cm samples measure 280 mm in the distance for male, which is 22 mm shorter than that for female. On the contrary, the 150 cm samples do 401 mm in the distance for male, which is 5 mm longer than that for female. Therefore, the rate of the distance-increment of the samples in the range from 100 cm to 150 cm in body length is greater for male than for female, being about 43 percent for male and about 31 percent for female. Equations of regression are given below and Table 4 showing these computed values.

$y=0.242039\ x+3.75$ ·····Male
$y=0.187741\ x+11.41$ ·····Female

(ii) **Distance from tip of snout to insertion of second dorsal fin** : The 100 cm samples measure 546 mm in the distance for male, which is 4 mm longer than that for female. On the contrary, the 150 cm samples do 754 mm in the distance for male, which is 11 mm shorter than that for female. This is the very reverse of (i). Therefore, the rate of the distance-increment of the samples in the range from 100 cm to 150 cm in body length is greater for female than that for male, being about 41 percent for female and about 38 percent for male. It may be said, therefore, that the distance between the first and second dorsal fins is longer for male than for female with small samples, and that the exact reverse is the case with large samples. Equations of regression are given below and Table 4 showing these computed values.

$y=0.414999\ x+13.13$ ·····Male
$y=0.446550\ x+9.50$ ·····Female

(iii) **Distance from tip of snout to insertion of anal fin** : The 100 cm samples measure 581 mm in the distance for male, which is 38 mm shorter than that for female. The 150 cm samples do 839 mm in the distance for male, which is 7 mm shorter than that for female, too. Therefore, the rate of the distance-increment of the samples in the range from 100 cm to 150 cm in body length is, as in the case of (i), greater for male than for female, being about 44 percent for male and about 37 percent for female. Equations of regression are given below and Table 4 showing these computed values.

$y=0.517922\ x+6.26$ ····· Male
$y=0.455108\ x+16.38$ ·····Female

3) Greatest body depth : The 100 cm samples measure 251 mm in the depth for male, which is 23 mm smaller than that for female. On the contrary, the 150 cm samples do 389 mm in the depth for male, which is 8 mm larger than that for female. Therefore, the rate of the depth-increment of the samples in the range from 100 cm to 150 cm in body length is greater for male than for female, being about 55 percent for male and about 39 percent for female. Equations of regression are given below and Table 4 showing these computed values.

$y=0.276144\ x-2.52$ ·····Male
$y=0.214391\ x+5.92$ ·····Female

Table 4. Comparison of some morphometric characters with sexes at each stage of 100 cm and 150 cm in body length.

Item	Sex	Male	Female
Head length	A	274mm	274mm
	B	387mm	380mm
	C	41.2 %	38.7 %
Snout to insertion of 1st dorsal fin	A	280	302
	B	401	396
	C	43.2	31.2
Snout to insertion of 2nd dorsal fin	A	546	542
	B	754	765
	C	38.1	41.0
Snout to insertion of anal fin	A	581	619
	B	839	846
	C	44.4	36.7
Greatest body depth	A	251	274
	B	389	381
	C	55.0	39.1

Note : A and B are body length 100 cm and 150 cm but C is growth rate (%).

4) Composition of body length and body weight : Body length of males ranges from 78—155 cm and about 52 percent have body lengths ranging from 121—130 cm, constituting of one major mode. Of females this ranges from 115—150 cm and about 43 percent have body lengths ranging from 121—130 cm and about 33 percent from 131—140 cm, thus constituting of two major modes. Of the total number of males and females, about a half have body lengths ranging from 121—130 cm and about a quarter from 131—140 cm. Table 5 shows these composition of body length.

Table 5. Comparison of composition of body length with sexes.

Body length	Composition of body length					
	Male		Female		Total	
70— 100 cm	4	13.8 %	0	0 %	4	5.1 %
101—110	0	0	0	0	0	0
111—120	1	3.5	3	6.1	4	5.1
121—130	15	51.7	21	42.8	36	46.2
131—140	4	13.8	16	32.7	20	25.6
141—150	3	10.3	9	18.4	12	15.4
151—160	2	6.9	0	0	2	2.6
Total	29		49		78	

Body weight of males ranges from 24—174 lbs and about 38 percent have body weights ranging 81—100 lbs and another 38 percent from 101—130 lbs, thus constituting of two major modes. Of females this ranges from 75—154 lbs, about 39 percent have body weights ranging from 81—100 lbs and 41 percent from 101—130 lbs, thus, like males in the same weight bracket, constituting of two major modes. However, the ratio of females weighing more than 100 lbs is slightly greater than that of males in the corresponding weight bracket. Table 6 shows these composition of body weight.

Table 6. Comparison of composition of body weight with sexes.

Body weight	Composition of body weight					
	Male		Female		Total	
20~ 40 lbs	4	13.8 %	0	0 %	4	5.1 %
71~ 80	0	0	3	6.3	3	3.8
81~100	11	37.9	19	38.8	30	38.6
101~130	11	37.9	20	40.8	31	39.7
131~150	0	0	7	14.1	7	9.0
151~180	3	10.4	0	0	3	3.8
Total	29		49		78	

7. Fishing and oceanographic conditions

Fishing operations were conducted on 12 occasions during the period from January 1st to 13th, 1961 (operations suspended on Jan. 4th due to rough sea). A total of 1,495 baskets (7,475 hooks) is used, and the catch of 299 consisted of yellowfin tunas, albacores and other fishes, and the average angling rate was 4.0 percent. The greater part of the catch was comprised of yellowfin tuna and albacore, the former numbering 116 (38.8 %) and the latter 114 (38.1 %), followed by 41 bigeyed tuna (13.7 %) and 18 marlins (6.0 %).

As for areas of operations, yellowfin tuna were mainly caught in the waters north of 35° S lat., albacore were caught in all the waters that we covered. These waters, therefore, may be regarded as an albacore fishing ground. Bigeyed tuna and sharks were caught from the most part in the southwestern waters where the thermocline is great, while marlins were caught in the middle of the waters (38°—41° E long., 32°—37° S lat.) with a high-temperature water mass at the bottom.

The surface water temperature was the lowest on the southwestern waters (operated on Jan. 3), being 17.7°C, and the highest on mid-northern waters (operated on Jan. 9), being 25.3° C. The distribution of surface water temperature was 25° C in the northern waters, became lower as we proceeded southward, and was 18° C in southern waters. At the 50 m depth, the water temperature generally follow suit after the surface water temperature, being high in the north and low in the south. At the 100 m depth, an 18° C water mass extends generally along 40° E long. to the vicinity of 37° S lat. At the depth of more than 100 m, changes in the water tempe-

rature show a generally similar tendency. At the 500 m depth, the water temperature is low in the southwestern waters, and in its center, as in the case of the 100 m depth, a tongue-shaped 16° C water mass extends from north toward south.

Since no tuna fishing has ever been carried out in these waters, I hesitate in examination making any further criticism of a fishing and oceanogrophic conditions. Details of those fishing operations are given in Table 7.

Table 7. Details of the tuna longline fishing in the southwestern waters of the Indian Ocean (Jan. 1—13, 1961).

Dates	Locations		Weather and sea water temperature					
	E long.	S lat.	Weather	Wind		Atmos. press.	0	50
				Direction	Force			
Jan.						mb.	°C	°C
1	30°——59′	33°——05′	b	NE	1	1,031	22.0	——
2	32 ——38	35 ——46	b c	NNE	1	1,024	19.0	18.0
3	34 ——56	38 ——56	c	N	3	1,014	17.7	18.3
5	38 ——30	36 ——58	c	NW	3	1,004	21.0	19.1
6	37 ——11	34 ——27	b c	W	4	1,010	21.8	22.4
7	36 ——26	32 ——01	b c	W	3	1,014	23.2	23.5
8	36 ——11	29 ——06	b c	E	1	1,016	24.2	22.7
9	39 ——45	28 ——57	c	E	2	1,013	25.3	25.5
10	41 ——13	31 ——46	c	SSE	1	1,016	25.0	23.0
11	43 ——23	34 ——09	c	N	2	1,019	22.8	20.6
12	45 ——17	31 ——47	b c	NNE	1	1,019	23.5	22.6
13	44 ——00	29 ——17	b c	NE	2	1,018	24.3	23.8

Depth (m)			GEK records		Operations		Yellowfin	Albacore
100	200	500	Direction	Speed	Number of hooks	Soaking time		
°C	°C	°C		Knots		h m h m		
——	——	——	294°	1.4	490	3—30→12—10	22(3)	——
15.9	13.4	9.8	133	1.9	490	3—20→12—05	1	1(1)
15.6	13.0	10.7	72	1.3	745	3—15→14—10	——	11
19.3	17.9	——	25	0.2	495	3—20→12—00	——	38
19.7	19.4	16.4	60	0.9	745	3—30→14—00	12	11
16.2	17.2	——	350	0.6	745	3—30→14—10	24(1)	21
16.8	17.2	13.3	230	0.7	495	3—30→12—00	14	4
21.7	20.2	16.3	200	0.9	495	3—30→11—55	12	4
20.0	17.5	——	162	0.4	750	3—30→14—00	8	13
17.3	16.2	13.5	330	0.6	750	3—30→13—20	——	——
17.2	16.2	16.6	160	0.8	750	3—30→13—15	6	1
17.8	17.7	14.5	243	0.8	525	3—30→11—55	12(1)	9
			Total		7,475	113—35	111(5)	113(1)

Captured fishes							Angling rate per 100 hooks
Bigeye	Marlins			Sharks	Others	Total	
	Black	Broadbill	Shortnose				
—	2	—	—	1	—	25(3)	5.7%
—	—	—	—	1	—	3(1)	0.8
29(1)	—	—	—	1	—	41(1)	5.6
—	—	—	1	1	Opah— 1 Dorado— 1	42	8.5
3	—	1	1	—	Dorado— 1	29	3.9
3	2	1	1	—	Skipjack— 1	53(1)	7.2
—	—	—	1	—	—	19	3.9
—	—	—	—	—	—	16	3.2
5	1	—	4	—	—	31	4.1
—	—	—	—	2	—	2	0.3
—	3	—	—	—	—	10	1.3
—	—	—	—	—	—	21(1)	4.2
40(1)	8	2	8	6	4	292(7)	(Average) 4.0

Note : Weather and sea water temperature observed in 5 h～7 h a. m.
G E K : Geomagnetic Electro-Kinetograph (used occasionally).
Number in brackets is injured fishes.
Jan. 4 th, no fished due to rough sea.

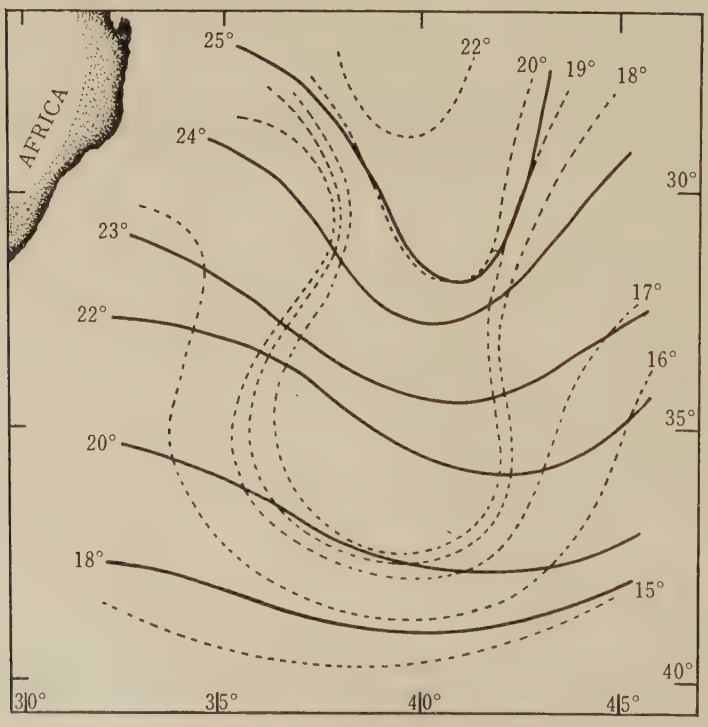

Fig. 2. Thermocline topography (Jan. 1～13, 1961). Note : —— 0 m, ·····100 m depth.

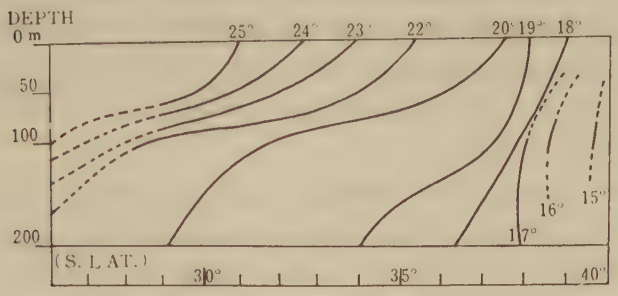

Fig. 3. Vertical distribution of water temperature at 40° E long.

Discussion

With our yellowfin tuna samples obtained in the southwest of the Indian Ocean, the rate of growth of various parts is as much the greatest at the second dorsal fin and anal fin, and the smallest at the pectoral fin as in the case of samples of the other waters.

1. External morphometric characters

1) **Head length** : With the 100 cm sample, head length is longer than that of the samples of any other waters. With 150 cm sample, head length is longer than that of the Hawaiian counterpart, but shows little difference when compared with samples of the other waters. The rate of the head length-increment of the samples in the range from 100 cm to 150 cm in body length is smaller than that of the samples of any other waters. In this regard, our samples, it may be said, therefore, compared with samples of corresponding body lengths obtained in the other waters, head length is longer in small specimens (body length under 100 cm), and, on the contrary, shorter in large specimens (body length above 150 cm).

2) **Distance from tip of snout to insertion of first dorsal fin** : Regardless of body length, the distance of this is shorter than that of of any other waters. The rate of this distance-increment is, like that of head length, low.

3) **Distance from tip of snout to insertion of second dorsal fin** : With the 100 cm sample, the distance is, contrary to 2), longer than the samples' of any other waters. With the 150 cm sample, the distance sampleis a little longer than that of the west of the mid-Pacific Ocean's, but shorter than that of the other waters'. The rate of this distance-increment of the samples in the range from 100 cm to 150 cm in body length is smaller than that of any other waters. It may be said, therefore, that the distance between the first and second dorsal fins of this sample is longer in small specimens than those of corresponding size in the other waters.

4) Distance from tip of snout to insertion of anal fin : Regardless of body length, this distance of this sample is generally longer than that of the other waters. The rate of this distance-increment, however, is smaller than the that of other waters.

5) Height of second dorsal fin : The height is, in general, shorter than that of the east Indian Ocean and the southwest Pacifics', but longer than that of the samples of the other waters.

6) Length of pectoral fin : Regardless of body length, the length of the pectoral fin is, as in the case of 2), shorter than that of any other waters. The rate of this length-increment is smaller than that of Angola and Hawaiian's, but greater than that of the other waters.

7) Height of anal fin : With the 100 cm sample, this height is lower than that of the east Indian Ocean and southwest Pacific's, but higher than that of the other waters. With the 150 cm sample, the height indicates genarally greater differences from that of the other waters. The rate of this height-increment of the samples in the range from 100 cm to 150 cm in body length is greater than that of the east Pacific's, and generally smaller than that of the other waters.

8) Greatest body depth : With the 100 cm sample, this depth is larger than that of the north of the mid-Indian Ocean's, but smaller than that of the other waters. With the 150 cm sample, the depth is generally larger than that of the other waters.

Table 8. Regression coefficients for various dimensions on total length, for samples from off the SW of the Madagascar I., Indian Ocean, Pacific Ocean and Angola.

Locals	Head length	Insertion I.D.F.	Insertion II.D.F.	Insertion A. F.	Height of I.D.F.	Length of P. F.	Height of A.F.	Greatest body depth	Body weight
SW of the Madagascar I.	0.22121	0.23466	0.39057	0.51222	2.00175	41.952	1.99463	0.26176	2.39295
Middle of the Indian Ocean	0.23234	0.26052	0.49268	0.50906	——	25.873	2.48733	0.28115	2.61155
SE of the Arabian Sea	——	0.25571	0.48074	——	2.17188	——	——	0.28803	2.95796
SW of the Greater Sunda Is.	0.23417	0.27687	0.43915	0.50854	2.51378	36.943	2.58067	0.25091	2.88983
SW of the Pacific Ocean	0.21202	0.20971	0.40469	0.42184	1.58926	25.284	1.90955	0.18083	2.43006
Hawaiian waters	0.22567	0.24821	0.46914	0.51941	2.21305	49.193	2.28934	0.25469	2.99587
W coast of America	0.24356	0.26148	0.48358	0.54383	——	——	——	——	——
Costa Rica	0.23504	0.26346	0.47675	0.53508	——	——	1.81538	0.25550	2.94457
Angola	0.22380	0.24190	0.45840	0.50210	1.89473	53.741	2.00815	0.26775	——

9) **Body weight** : With the 100 cm sample, this weight is heavier than that of any other waters. With the 150 cm sample, the weight is lighter than that of the east Arabian Sea's, but generally heavier than that of the other waters. Table 8 gives coefficients for x in equations of regression indicating the foregoing characteristics of the samples in various waters.

2. Ratio of sexes and morphometric differences

1) **Ratio of sexes** : According to our previous data, the male-female ratio of yellowfin tuna in the Indian Ocean increases, as we proceed northward or eastward, in favor of males. The data also show that in the eastern waters the majority are male. Our study on the samples of the waters covered by present report, however, has revealed that above 30° S lat. the majority are female, and that under this latitude the number of males increases as we proceed northward, but females are still predominant in number. It may be assumed, therefore, that in the Indian Ocean of January males constitute of the majority in the northeastern waters, while females are predominant in number in the southwestern waters.

2) **Morphometric differences** :

(1) **Head length** : With the 100 cm sample, no difference is noted among male and female. With the 150 cm sample, this length is slightly longer for male. From this, the rate of the head length-increment is larger for male, and that difference grows wider according to the body length increases.

(2) **Distance from tip of snout to insertion of first dorsal fin** : With the 100 cm sample, this distance is longer for female. On the contrary, with the 150 cm sample, the distance is longer for male. From this, it is understood that the rate of the distance-increment is larger for male, and that difference grows wider according to the body length increases or decreases.

(3) **Distance from tip of snout to insertion of second dorsal fin** : With the 100 cm sample, this distance is a little longer for male. On the contrary, with the 150 cm sample, the distance is longer for female. It may be said, therefore, that the rate of the distance-increment is, contrary to (2), larger for female, and that the distance between the first and second dorsal fins is longer for male in small specimens and longer for female in large ones.

(4) **Distance from tip of snout to insertion of anal fin** : With the both 100 cm and 150 cm samples, this distance is longer for female. The rate of the distance-increment, however, is larger for male, and that difference, therefore, became smaller according to the body length increases.

(5) **Greatest body depth** : With the 100 cm sample, this body depth is larger for female. On the contrary, with the 150 cm sample, the depth is larger for male. It is understood, that the rate of the depth-increment is greater for male, and that difference grows wider according to the body length increases or decreases.

3) **Composition of body length and body weight** :

(1) **Composition of body length** : The majority have body lengths ranging from 121—140 cm. Both sexes, those in the 121—130 cm bracket constitute of the major group, but females constitute of the second major group in the 131—140 cm bracket.

(2) **Composition of body weight**: The majority have body weights ranging from 81—130 lbs (37—59 kg). Both sexes, those in the 81—100 lbs (37—45 kg) bracket and in the 101—130 lbs (46—59 kg) bracket each constitute of two modes. The number of females in the latter bracket is slightly larger than that of males.

Conclusion

As the result of comparison between our yellowfin tuna samples caught in the southwestern of the Indian Ocean and those of the other waters, it may be summarized as follows :

1. **Head length**: The length is larger in small specimens (body length under 100 cm), and smaller in large specimens (body length above 150 cm).

2. **Distance from tip of snout to insertion of first dorsal fin** : The distance is shorter regardless of body length.

3. **Distance from tip of snout to insertion of second dorsal fin** : The distance is longer in small specimens, and generally shorter in large specimens. It may be said, therefore, that the distance between the first and second dorsal fins is longer in small specimens.

4. **Distance from tip of snout to insertion of anal fin** : The distance may be said to be generally longer regardless of body length.

5. **Height of second dorsal fin** : The height may be said to be generally higher regardless of body length.

6. **Length of pectoral fin**: The length is shorter regardless of body length.

7. **Height of anal fin**: The height, although higher than the east Pacific and Angola samples, may be said to be generally lower.

8. **Greatest body depth**: With small specimens, excluding mid-Indian Ocean's, the depth is generally smaller than that of the other samples, but large specimens, excluding Angola's, the depth is larger than that of the other samples.

9. **Body weight**: The weight is generally heavier regardless of body length. This tendency, however, turns downward according to the body length increases, since the rate of the body weight-increment is low.

10. **Differences between male and female** :

(1) **Head length**: Little difference is detected in small specimens, but in large ones the length is longer for male.

(2) **Distance from tip of snout to insertion of first dorsal fin:** The distance is longer for female in small specimens, and longer male in large ones.

(3) **Distance from tip of snout to insertion of second dorsal fin:** The distance is longer for male in small specimens, and longer female in large ones. The distance between the first and second dorsal fins, therefore, is longer for male in small specimens, and longer female in large ones.

(4) **Distance from tip of snout to insertion of anal fin:** The distance is longer for female regardless of body length. The difference, however, becomes smaller according to the body length increases, since the rate of the distance-increment is larger for male.

(5) **Greatest body depth:** The depth is larger for female in small specimens, and larger male in large ones.

As is apparent from the foregoing, many unique characteristics and some similarity to other samples are noted. The most notable discovery is that, as is clear from Tables 3 and 8, our samples present much resemblance to the Angola's than the any other waters', in the rate of growth of fin insertion, greatest body depth and height of anal fin, when their body length has grown from 100 cm to 150 cm. The Angola waters are on the other side of the African continent, and those waters that we covered are presumed to be partitioned with each other by the *West Wind Drift* which surrounds the Antarctica. However, NAKAMURA and YAMANAKA[5] have reported that in the Indian Ocean tunas have a property of distributing themselves according to systematic ocean currents.

The Atlantic tuna form has those characters found among Pacific tuna form, the so that the Pacific fishes are atmost identical with the Atlantic fishes, again the Atlantic fishes are similar to those of the Indian Ocean as reported by BEEBE and TEE-Van (1936), on these facts that our samples bear more resemblance to the samples of farther waters than to those of near waters, i.e. the Indian Ocean, provide grounds for the assumption that the yellowfin tuna, too, forming partly independent stocks all over the world but probably referable to a single species.

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